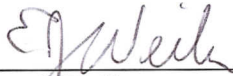




# **Earth System Science Pathfinder Program Office**

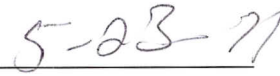
## **Program Plan**

**Earth System Science Pathfinder Program Office**  
NASA Langley Research Center  
Hampton, VA 23681



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## 1.0 PROGRAM OVERVIEW

### 1.1 Introduction

The Earth System Science Pathfinder (ESSP) Program is a strategic investment by the Science Mission Directorate (SMD) Earth Science Division (ESD) that includes a series of relatively low-to-moderate cost, small-to-medium sized, competitively selected, Principal Investigator-led missions that are built, tested, and launched in a short time interval that accommodate new and emergent scientific priorities. ESSP Projects are operational and developmental, high-risk, high-return orbital and sub-orbital Earth Science missions and advanced remote sensing instruments for missions of opportunity; they often involve partnerships with other U.S. agencies and/or with international science and space organizations. These support a variety of scientific objectives related to Earth Science, including the atmosphere, oceans, land surface, polar ice regions, and solid Earth. ESSP Projects encompass the entire life cycle from definition, through design, development, integration and test, launch or deployment, operations, science data analysis and distribution. The ESSP Program Office, located at Langley Research Center, is the management structure established by ESD that is responsible for the management, direction, and implementation of the ESSP program elements.

ESSP Projects are encouraged to take advantage of opportunities arising from domestic and international cooperative efforts or technical innovation, consistent with recommendations issued by the National Research Council in their 2007 report, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (Decadal Survey).

The projects within the ESSP Program are: (1) legacy and future competitively-selected orbital projects; (2) non-competitive, directed projects that are designed to meet unique needs, such as the replacement of a mission that did not fulfill its intended mission requirements; and (3) the Earth Venture (EV) series of uncoupled, relatively low-to-moderate cost, small to medium-sized, competitively selected, orbital and sub-orbital projects that are built, tested and launched short time intervals.

The Principal Investigator (PI) for each competitively selected project is responsible for the overall success of the Project and is accountable to NASA for the success of the mission. Project teams may include academia, industry, government, Federally Funded Research and Development Centers (FFRDC), and international partners, as desired by the PI.

### 1.2 Goals and Objectives

ESSP Program goals and objectives trace to Agency needs, goals, and objectives via SMD and Earth Science Division (ESD) strategic planning. The *2011 NASA Strategic Plan* specifies six Strategic Goals for the Agency. SMD is responsible for defining, planning, and overseeing NASA's space and Earth Science programs to enable the Agency's Strategic Outcome 2.1: "Advance Earth system science to meet the challenges of climate and environmental change."

The *2010 Science Plan: For NASA's Science Mission Directorate* (Science Plan) details how SMD will turn NASA's science vision into scientific discovery. The Science Plan identifies six Earth Science Research Program Science Focus Areas: **atmospheric composition, weather,**

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**carbon cycle and ecosystems, water and energy cycle, climate variability and change, and Earth surface and interior.** There are seven Earth Science Objectives, which are associated with these six areas. These are the benchmarks against which sponsors in the Agency and stakeholders in the science community measure NASA Earth Science progress:

1. Improve understanding of and improve the predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition.
2. Enable improved predictive capability for weather and extreme weather events.
3. Quantify, understand, and predict changes in Earth's ecosystems and biogeochemical cycles, including the global carbon cycle, land cover, and biodiversity.
4. Quantify the key reservoirs and fluxes in the global water cycle and assess water cycle change and water quality.
5. Improve understanding of the roles of oceans, atmosphere, land, and ice in the climate system and improve predictive capability for its future evolution.
6. Characterize the dynamics of Earth's surface and interior and form the scientific basis for the assessment and mitigation of natural hazards and response to rare and extreme events.
7. Enable the broad use of Earth system science observations and results in decision-making activities for societal benefits.

The ESSP Program goal is to stimulate new scientific understanding of the global Earth system through the development and operation of remote-sensing missions and the conduct of investigations utilizing data from these missions to address unique, specific, highly focused requirements in Earth science research. The ESSP objectives to achieve this goal are to:

- Provide periodic opportunities for competitively selected, PI-led Projects addressing NASA's high priority Earth system science outcomes that are built, tested, and launched or deployed in a short time interval
- Contain Project and mission costs through commitment to, and control of, design, development, and operational costs within the risk and technical standards established by the Agency

ESSP Projects pursue science investigations in one or more of the six Earth Science Research Program Science Focus Areas and promote the outcomes listed above. By looking at properties of the Earth system in innovative ways, the Earth Science community can understand variability, forcing, and response mechanisms from new perspectives. ESSP provides flexible opportunities to stimulate new scientific understanding by encouraging increased participation by small projects and creativity in all aspects of project development; the implementation of these leads to



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new strategies for acquiring and distributing datasets. ESSP Projects also demonstrate measurement techniques for application on future Earth Science operational missions.

ESSP Program Office internal goals and objectives articulate an approach undertaken by the ESSP Program Office to enable constituent projects to meet their science objectives, while managing performance to cost, risk, schedule, and technical standards established by the Agency.

***GOAL #1: Support ESD efforts to achieve NASA Earth Science goals by assisting in the development of competitive solicitations to the Earth Science community for innovative orbital and sub-orbital projects, and by leading directed projects as assigned.***

- Objective 1a: Support the ESD as requested in the development of open solicitations for innovative Earth Science projects.
- Objective 1b: Initiate an ongoing communications and outreach effort to inform, educate, and encourage a broad-based pool of capable proposers.
- Objective 1c: Collect lessons learned from solicited and directed ESSP missions and share this knowledge to improve flight operations and promote best practices across the Earth Science Division.

***GOAL #2: Create a management environment for Projects conducive to successful delivery of Earth system science within agreed-to cost, schedule, and technical parameters at a level of risk acceptable to NASA.***

- Objective 2a: Regularly and actively engage ESSP Projects through formal and informal channels and across working levels to stay informed of Project activities and cost, schedule, and technical status in order to more effectively advocate for Projects with stakeholders.
- Objective 2b: Perform regular assessment of risk across ESSP Projects in order to inform and advise ESD on the deployment of division-level resources to promote efficient, effective risk-based decision making within the Program and Projects.
- Objective 2c: Prepare and provide educational / guidance materials for newly selected PIs, and conduct activities to educate PIs / Project Managers on NASA policies governing cost, schedule, risk and technical standards.
- Objective 2d: Regularly engage ESD through formal and informal channels and across working levels to more effectively anticipate ESD requirements on behalf of Projects.

***GOAL #3: Promote an atmosphere of productive engagement and open communication within the Program, across NASA organizations, and externally to the public.***

- Objective 3a: Conduct deliberate, scheduled program “Pause and Learn” sessions to share knowledge and experiences, to share customer feedback, to build consensus, and to establish a common vision among Program Office personnel.

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- Objective 3b: Conduct regular interactions with other ESD organizations to leverage programmatic efficiencies within the Division.
- Objective 3c: Regularly engage critical support services across NASA to better anticipate and mitigate risks to Projects and promote effective use of Agency resources.
- Objective 3d: Execute an Education and Public Outreach (E/PO) strategy coordinated with ESD and the ESSP projects to further NASA and ESD's objectives.

### **1.3 Program Architecture**

The ESSP Program is classified as uncoupled and is composed of a series of competitively selected, PI-led, cost-capped, orbital, and sub-orbital projects, and of directed projects assigned to the Program by SMD. These projects are independent of one another in terms of science objectives, mission requirements, or technical interdependencies yet integrated to the Program through a common funding and management structure. Each project operates independently in achieving its unique set of mission science objectives, which directly contribute to the Program objectives. In addition, the projects often identify beneficial synergies provided by coincident measurements from other NASA Projects (ESSP or non-ESSP) that enhance the overall science return.

Most ESSP Projects have been selected from proposals submitted in response to Announcements of Opportunity (AO) and NASA Research Announcements (NRA) released in 1996, 1998, 2001, and 2009 and are listed in Appendices G through Q. Taken together, the Program Office and respective projects constitute the major components of the program architecture.

Table 1-1 identifies the projects and their current status for the ESSP Program.

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**Table 1-1: ESSP Project Portfolio**

| Project                  | Date               | Phase   | Status                   |
|--------------------------|--------------------|---------|--------------------------|
| Orbital Missions         | Launch             |         |                          |
| GRACE                    | Mar-02             | Phase E | Extended Operations      |
| CALIPSO                  | Apr-06             | Phase E | Extended Operations      |
| CloudSat                 | Apr-06             | Phase E | Extended Operations      |
| Aquarius                 | Jun-11             | Phase D | Implementation           |
| OCO-2                    | Feb-13             | Phase C | Implementation           |
| Earth Venture 1          | Initial Deployment |         |                          |
| AirMOSS                  | Jun-12             | Phase B | Formulation              |
| ATTREX                   | Sept-11            | Phase B | Formulation              |
| CARVE                    | Jun-11             | Phase B | Formulation              |
| DISCOVER-AQ              | Jun-11             | Phase B | Formulation              |
| HS3                      | Aug-12             | Phase B | Formulation              |
| Future Solicitations     |                    |         |                          |
| Earth Venture 2          |                    |         | Solicitation Formulation |
| Earth Venture Instrument |                    |         | Solicitation Formulation |

In addition to the above projects, the ESSP Program Office implements special studies and special projects to support the Program Activities. These studies can include areas such as mission feasibility and instrument accommodations. A special project led by the Program Office that is crosscutting across all Earth Venture Instrument projects is known as the Common Instrument Interface (CII) project. This project defines guidelines for Instrument to Spacecraft interfaces and may develop simulators for which proposers of instruments to the Earth Venture Instrument AO can utilize in order to facilitate the accommodation of the instrument on missions of opportunity. The purpose of the CII project is to control the costs of instrument to spacecraft interface design and implementation.

### 1.3.1 Program Interfaces with Organizations Within and Outside NASA

ESSP Projects will enter into formal agreements with organizations within and outside NASA as needed to support the objectives and requirements of the individual Projects. Examples of other organizations with which Projects may engage include: NASA Launch Services Program, Space Communications and Navigation (SCaN), the Rapid Spacecraft Development Office (RSDO), the Airborne Science Program, and Sub-orbital Projects. The ESSP Program Office may facilitate the interaction between the Project and the responsible NASA organization to ensure timely implementation of the agreements.

Projects that require external agreements with respect to other US Agencies, industry, and academia will also make direct contact to reach agreement for support. Projects involved with international non-NASA partner will work with SMD and the NASA Office of International and Interagency Relations to generate the appropriate agreement and approvals. These external agreements are referenced in the individual Project Plans.

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The ESSP Program Office supports the ESD as the ESD develops the framework for solicitations and is an observer in the evaluation and selection process. The ESSP Program Office assumes management responsibility for the selected projects.

#### **1.4 Stakeholder Definition and Advocacy**

ESD and the Earth Science community are the immediate stakeholders for the ESSP Program. ESD provides the ESSP Program with its operating budget, programmatic guidelines, and identification of scientific goals and objectives. The Earth Science community is the principal user of data resulting from ESSP Projects and provides the intellectual guidance and rationale for the measurements and science investigations. These data are also utilized by commercial users; federal, state, local, and international public sector users; the educational community; public media; and technology users.

Programmatic advocacy comes from the ESD Director, the Associate Administrator for Science Mission Directorate (SMD AA), and the NASA Administrator in their budgetary submittals to Congress and by the Congress via its authorization and appropriation of the funding necessary to implement the Program. Program Office advocacy with SMD is achieved through monthly reporting and interaction among the Program Manager (PM), Program Executives (PE), and the ESD Associate Director for Flight Programs. The ESSP Program Office also engages with other NASA organizations, including the Earth Science Technology Office (ESTO), as well as the Applied Sciences and Research elements of ESD to promote mission success.

Stakeholder advocacy is achieved through interactions with the Earth Science community and with the general public interested in Earth science. These interactions involve the NASA HQ ESD, NASA Advisory Committee (NAC) Earth Science Subcommittee (ESS), Project Scientists, PIs, Advisory Committees and non-scientific user groups.

The ESSP Program Office engages the Earth Science community through formal and informal interactions. Formal interactions include participation in ESD led solicitation pre-proposal conferences, PI forums, project science meetings, or advisory committee meetings. Informal interactions include periodic lessons-learned workshops to solicit feedback on program processes.

The Program Office recognizes that the general public is a key stakeholder. Helping the public understand Earth Science and the activities of ESSP is important to the Program and to NASA. The Program Office engages the public by supporting invitations to speak at community educational forums, Earth Science events, or at nearby schools. The ESSP Program also seeks out forums in the professional communities such as those conducted by the Institute of Electrical and Electronics Engineers (IEEE), the American Institute of Aeronautics and Astronautics (AIAA), and the American Geophysical Union (AGU).

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## **1.5 Program Authority, Management Approach and Governance Structure**

ESSP is an uncoupled, multiple-project program with program management authority delegated by the SMD AA through ESD to the ESSP Program Manager located at Langley Research Center (LaRC). The Agency Program Management Council (PMC) is the governing PMC for the ESSP Program, while the Science Mission Directorate PMC governs the scientific and strategic management of the individual ESSP Projects.

The ESSP Program follows program governance and implementation guidelines for space investigations in a manner consistent with *NASA Space Flight Program and Project Management Requirements* (NPR 7120.5) and with the *Science Mission Directorate Management Handbook* (SMD Handbook). In specific instances dealing with sub-orbital investigations, ESSP follows *NASA Research and Technology Program and Project Management Requirements* (NPR 7120.8). For all projects, ESSP includes best practices and implementing Center requirements as sources of guidance.

### **1.5.1 Management Approach**

The ESSP program management structure consists of three principal levels of authority:

- 1) Scientific and strategic management within SMD
- 2) ESSP program management at LaRC (program implementation)
- 3) Management of individual ESSP investigations by their respective project teams

The SMD AA is the Selecting Official and the Decision Authority (DA) for ESSP Projects, unless precluded from doing so because of conflicts of interest. The SMD AA has designated the ESD Director as the senior Agency official who serves as the SMD focal point for ESSP scientific and strategic management.

Program management responsibility for implementation has been assigned to the ESSP Program Manager, located at LaRC; the LaRC Center Director is responsible for providing the Center resources required to execute the Program. Programmatic authority is delegated from the SMD AA to the ESD Director to the Associate Director for Flight Programs to the ESSP PM. The Program Office oversees projects' implementation to ensure technical, cost, and schedule commitments are met, and advocates for projects with ESD and SMD.

Management authority for each ESSP investigation is assigned to the respective PI. Each PI is responsible for the overall success and safety of his/her investigation and is accountable to the SMD AA for the scientific success and to the ESSP PM for the programmatic success. In cases where there is no PI, the Project Manager (PM) will assume the PI responsibilities. An ESSP PI may delegate project management responsibilities to a Project Manager who may also report to the ESSP PM. A PI's NASA Center and/or home institution provides facilities, staff, and technical expertise.

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To achieve an unambiguous line of direction and reporting within these levels, all formal direction from SMD to the ESSP Program flows from the ESD Associate Director for Flight Programs to the Program Manager. Similarly, to ensure an unambiguous line of direction and reporting with ESSP Projects, all formal direction from the Program to the Project flows from the Program Manager to the PI.

In order to ensure effective day-to-day dialogue between ESD and the Program Office, and to execute responsibilities held by ESD, the ESD Director selects ESD staff members to represent SMD and ESD to the Program. ESD staff who ensure this timely exchange include PEs, Program Scientists (PS), and Program Analysts (PA). Together the Program Office and the HQ staff form a team that is charged with managing/coordinating the entire suite of activities necessary to carry out ESSP Projects to their final successful phase. The team follows established processes for communicating progress, issues, and problems regularly to the ESD management.

Figure 1-1 illustrates the ESSP program management structure, including the relationships among key participants.

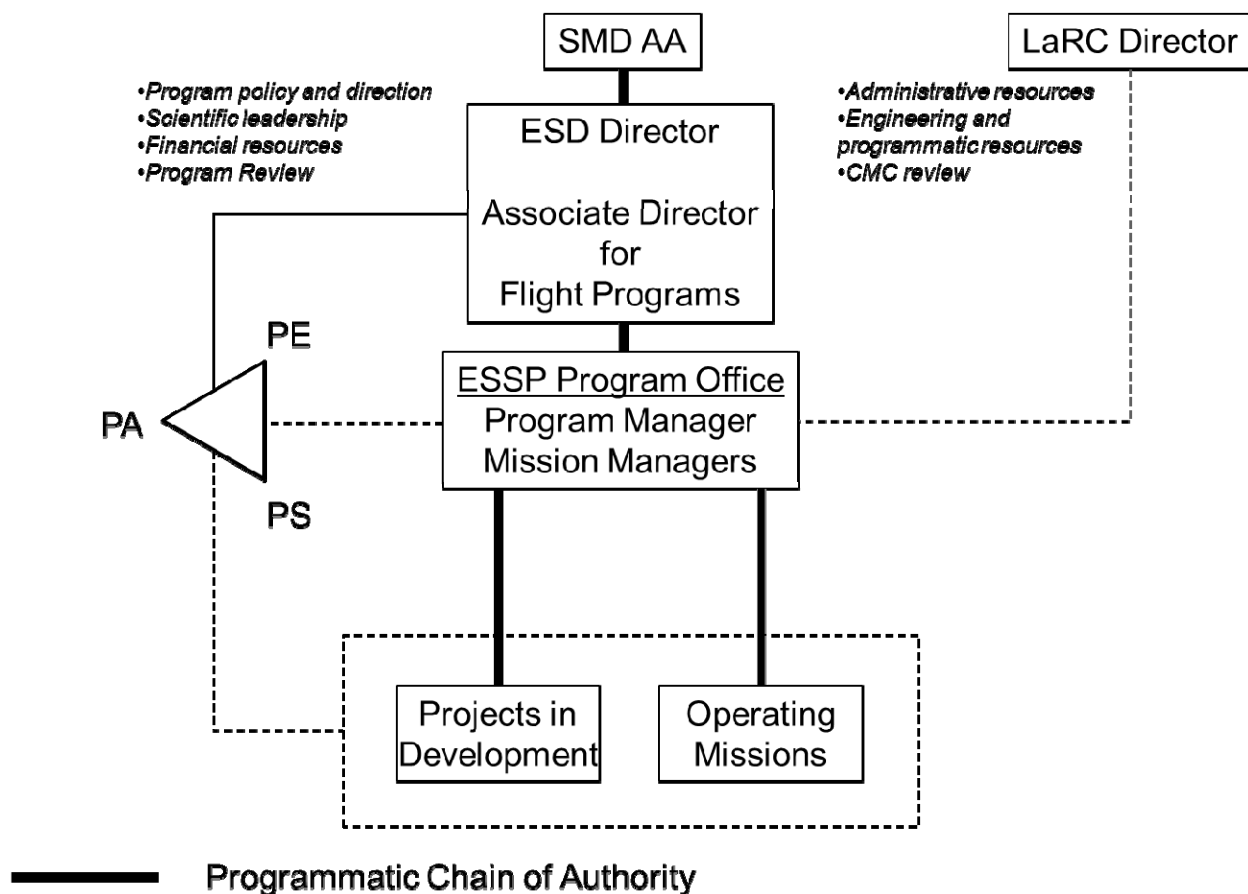


Figure 1-1: ESSP Programmatic Authority

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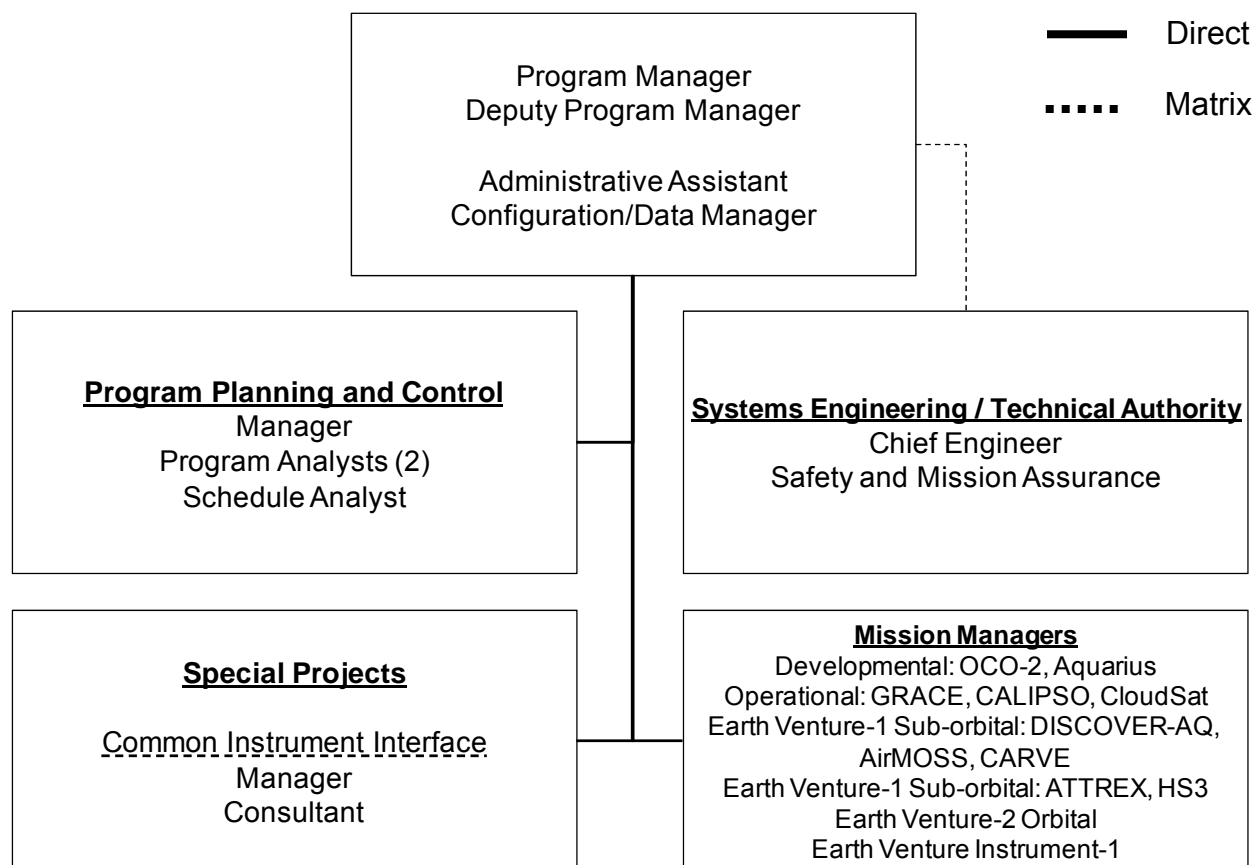
The following is a high-level description of roles and responsibilities of key individuals in the ESSP management and accountability chain.

- Science Mission Directorate Associate Administrator—is responsible for managing the programs within the SMD; serves as the KDP DA for ESSP Projects; is responsible for all program requirements, including budgets, schedules, and the high-level programmatic requirements levied on projects within the SMD.
- ESD Director—is delegated all Earth Science programmatic authority and responsibility from the SMD AA.
- ESD Associate Director for Flight Programs—defines, integrates, and assesses program/project activities and provides policy direction and guidance to the program/projects.
- ESSP Program Manager—is responsible for all facets of the ESSP Program. Section 1.5.2.1 provides specific PM roles and responsibilities.
- ESD Program Executives—represent ESD to the ESSP Program Office and Projects on all technical, management, and cost issues for an assigned Project.
- ESD Program Scientists—represent ESD to the ESSP Program Office and Projects on all science issues for an assigned Project.
- ESD Program Analysts—represent ESD to the ESSP Program Office and Projects on all financial resource issues for an assigned Project.
- ESSP Mission Managers—are responsible for ensuring Program Office support for Projects, leading the regular assessment of Projects' performance, identifying issues for which the Projects need assistance, and for maintaining effective working relations with the Projects.
- Center Directors—are responsible for establishing, developing, and maintaining the institutional capabilities (processes and procedures, human capital, facilities, and infrastructure) required for the execution of the ESSP Program and Projects. This includes the system of checks and balances to ensure the technical integrity of programs and projects assigned to the Center. Center Directors are also responsible for certifying readiness of the mission for launch and mission operations.
- ESSP Project Principal Investigator—is responsible for the scientific integrity of the investigation and is the lead for the ESSP Project team. The PI reports directly to the ESSP PM on all project-level matters.
- ESSP Project Manager—is responsible for the formulation and implementation of the Project per the governing agreement with the PM, if delegated from the ESSP Project PI.

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### 1.5.2 ESSP Program Office Roles and Responsibilities

The ESSP Program Office implements the Program on behalf of SMD. Figure 1-2 presents the current ESSP Program Office organization chart.



**Figure 1-2: ESSP Program Office Organization**

#### 1.5.2.1 *ESSP Program Manager*

The ESSP PM is responsible for planning and implementing the ESSP Program consistent with top-level policies, strategies, requirements, and funding established by NASA HQ. The PM's Roles and Responsibilities are discussed in detail in the SMD Handbook. For the ESSP Program, these include but are not limited to:

- Implementing the ESSP Program for the SMD-selected investigations
- Ensuring open communications with ESSP Program customers and communicating program customer needs to SMD
- Developing and managing program-level metrics to assess the performance and health of the Program
- Maintaining the ESSP Program Plan in accordance with NPR 7120.5



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- Independently evaluating and assessing program and project technical, schedule, and cost performance, and mitigating risk as appropriate
- Providing program technical experts as required to support the Projects
- Managing the ESSP Program implementation budget. Developing detailed program Operating Plans and Cost Phasing Plans for the implementation budget. Monitoring distribution of funds to implementing organizations
- Assessing the Program for Project liens and threats which could impact the ESSP Futures Budget
- Assigning a Program Office Mission Manager (MM) to each mission
- Conducting disposition of mission flight and ground hardware
- Assessing Program and Project readiness and recommending whether they should proceed past KDPs
- Supporting SMD in the initiation and preparation of ESSP solicitations
- Planning, coordinating, and implementing an E/PO program
- Communicating Project status to the ESD Associate Director for Flight Programs
- Recommending options to solve Program and Project challenges to the ESD Associate Director for Flight Programs

#### *1.5.2.2 ESSP Program Planning and Control Manager*

The ESSP Program Planning and Control Manager performs financial and programmatic management functions on behalf of the PM, ensuring the PM maintains an awareness of Project financial status and performance vs. plan, and that the financial needs of the Projects are being adequately addressed.

The Program Planning and Control Manager's responsibilities include, but are not limited to:

- Establishing and performing resources management oversight of Project contracts and task orders
- Independently evaluating Project schedule, management, and cost data and issues for the PM
- Identifying Project liens and threats that could result in cost cap breaches
- Coordinating Project funding requirements

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- Coordinating with the PA to ensure consistent budget direction between SMD and the Program Office
- Ensuring that appropriate Program resources are provided to the Projects in a timely manner
- Leading the Program Office planning and implementation of Planning, Programming, Budgeting, and Execution (PPBE) activities. Preparing information requests for all Projects and the Program Office and a schedule for submittal to the PM
- Providing monthly assessments of project performance by documenting commitments, obligations, and costs and explaining variances that exceed  $\pm 10\%$
- Providing monthly assessments of each Project's projected cost at the end of the FY vs. New Obligation Authority (NOA) anticipated at the end of the FY as well as total cost for all Projects vs. Total NOA to be provided to all Projects and the Program Office
- Alerting the PM at any time a Project's cumulative commitments, obligations, or costs are expected to exceed 95% of the NOA available
- Maintaining the program milestones/events calendar with at least monthly updates to reflect all significant Project and Program Office events
- Leading the Program Office regular reporting activities, including transmitting after report finalization and review, negotiating format, receiving and distributing project-level input, and assigning section drafting and submission schedules

#### *1.5.2.3 ESSP Program Chief Engineer*

The ESSP Program Chief Engineer (CE) is assigned systems technical authority for communicating technical excellence and exercising technical authority for the ESSP Program. The ESSP Program CE, in partnership with the ESSP PM, ensures an atmosphere of "checks and balances" within the ESSP Program and Projects. For Projects assigned to NASA Centers and the Jet Propulsion Laboratory (JPL), the Technical Authority for these Projects is delegated from the NASA Office of Chief Engineer directly to the engineering management at that Center. For any Projects assigned to non-NASA centers, the ESSP Program CE has NASA technical authority. The ESSP Program CE responsibilities include:

- Identifying and utilizing technical expertise from across NASA, industry, and academia to ensure investigation success and technical excellence through risk-based technical insight into the ESSP Projects
- Monitoring project execution and issue resolution
- Serving as a review team member

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- For ESSP Projects assigned to NASA Centers and JPL, working to seek resolution of identified issues. If resolution of the issues cannot be done at lower levels, then the CE communicates to the next level of Center or Agency technical authority
- For ESSP Projects assigned to non-NASA centers, retaining technical authority while working closely with the project-level engineering organization to delegate an appropriate level of insight responsibility to the non-NASA center's engineering authority. The CE resolves any identified issues at the lowest level of authority. Major unresolved issues shall be elevated to the next level of Center or Agency technical authority

#### *1.5.2.4 ESSP Mission Managers*

ESSP Program Office MMs function as the PM's day-to-day point of contact and advocate for all assigned Projects. They perform technical and programmatic management functions on behalf of the PM, ensuring the PM maintains an awareness of the Project status and that the programmatic needs of the assigned Projects are being adequately addressed. The MMs' responsibilities include:

- Serving as the NASA point of contact (POC) for Projects within the Program
- Interfacing directly with the PIs and Project Managers to develop inputs for program planning, integration, and project issue resolution
- Establishing and performing technical management oversight of project contracts and task orders
- Independently evaluating project metrics, schedule, cost data, management, and issues for the PM
- Independently assessing Projects to identify risks and mitigations
- Identifying Project liens and threats that could result in cost cap breaches
- Providing a monthly project assessment to the PM
- Coordinating with the PE to ensure the clear understanding of programmatic direction between SMD and the Program Office
- Serving as the Program Office representative among NASA, other U.S. governments agencies, and foreign participants on behalf of assigned investigations
- Serving as the Program Office advocate to NASA management, the Public, and other government entities for assigned Projects
- Leading the development of decision packages or products that are fully coordinated within the ESSP Program and with the related PIs and Project Managers

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#### *1.5.2.5 ESSP Program Safety and Mission Assurance Lead*

The ESSP Program Safety and Mission Assurance (SMA) Lead (*i.e.* Chief Safety and Mission Assurance Officer) is assigned systems SMA authority for communicating SMA excellence and exercising SMA authority for the ESSP Program. The ESSP Program SMA Lead, in partnership with the ESSP PM, ensures an atmosphere of “checks and balances” with the ESSP Program and Projects. For Projects assigned to NASA Centers and JPL, the SMA authority is delegated from the NASA SMA Office directly to the SMA group at that Center. For Projects assigned to non-NASA centers, the ESSP Program SMA Lead has NASA SMA authority. The ESSP Program SMA Lead responsibilities include:

- Ensuring mission success and safety through risk-based technical insight into the ESSP Projects
- Monitoring project execution and SMA issue resolution
- Serving as a review team member
- For ESSP Projects assigned to NASA Centers and JPL, working to seek resolution of identified issues. If the issue is not resolved at lower levels, the SMA Lead communicates it to the next level of the Center or Agency SMA authority
- For ESSP Projects assigned to non-NASA centers, the ESSP Program SMA Lead retains SMA authority while working closely with the Project SMA organization to delegate an appropriate level of insight responsibility to the non-NASA center’s SMA authority. The SMA Lead resolves any identified issues at the lowest level of authority

#### 1.5.3 Principal Investigator and Project Manager Roles and Responsibilities

Overall responsibility for scientific integrity and investigation success of each ESSP Project is vested with the PI. This individual is the lead scientist and organizes the team or consortium that develops the mission concept and implements the mission under the prescribed guidelines and constraints. The PI chooses the management approach best suited to the mission design, skills/expertise of the team members, and resources.

The SMD AA holds the PI accountable for proper execution of all aspects of the project, particularly as outlined in the original solicitation, accepted Concept Study Report, Project Plan, and Program-Level Requirements Appendix (PLRA). The PI must notify the ESSP PM if the successful achievement of the threshold scientific objectives is not possible within the prescribed programmatic constraints.

Project Managers are appointed by the implementing organizations with PI concurrence. Each ESSP Project Manager is responsible to the PI for the successful development and implementation of the Project.

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The ESSP Program Office interfaces directly with the PI or the Project Manager as delegated at the implementing organization, particularly in the areas of resource allocation and utilization, oversight, reporting, and resolution of project-level issues.

Each PI, with support from the Project Manager, has the following specific responsibilities:

- Serving as the primary scientific spokesperson for the mission and for the scientific investigations
- Assuring delivery of science data to the Distributed Active Archive Center (DAAC) and dissemination of scientific results through professional publications and E/PO
- Informing the ESD Program Scientist of status, changes, or results in the investigation science
- Representing the Project to NASA, other government agencies, industry, and institutions as required on matters pertaining to the investigation. The PI supports NASA in performing ESSP Program advocacy
- Requesting NASA concurrence on key personnel changes
- Planning, developing, and executing an investigation to achieve its scientific requirements in accordance with the PLRA and Project Plan
- Documenting the status of Level 1 Requirements, particularly mission science requirements, at End of Mission
- Developing project-level implementation plans, schedules, and budgets in accordance with program requirements, project objectives and constraints, and with other applicable NASA policies
- Communicating urgent or significant design, test, or operational anomalies to the PM
- Supporting independent assessments and confirmation reviews
- Managing the Project budget. The PI identifies and reports liens and threats and develops PPBE submittals and traces
- Implementing the Project's SMA processes
- Developing and implementing a risk management process through the project life cycle. The PI assesses and reports project-level risks to the ESSP Program
- Developing and maintaining the Project Plan in accordance with NPR 7120.5 or 7120.8

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- Developing and implementing the Project's E/PO activity, in coordination with the ESSP Program E/PO

#### 1.5.4 Science Mission Directorate Detailed Roles and Responsibilities

The Science Mission Directorate within NASA HQ is responsible for the scientific and strategic direction of the ESSP Program within the Earth Science theme. The SMD AA holds the final authority and responsibility for the ESSP Program.

##### *1.5.4.1 Program Executive(s) for ESSP Projects*

The PEs support the SMD AA in defining, integrating, and assessing the activities of ESSP Projects. Their roles and responsibilities are discussed in detail in the SMD Handbook. For the ESSP Program, these include but are not limited to:

- Maintaining cognizance of the Projects' programmatic health via regular interaction during formulation and implementation (Phases A, B, C, D, and E), via exposure to reports from the Project, monthly status and major milestone reviews, access to assessments coordinated by the Program Office, and ad hoc interactions deemed necessary to assess Project performance
- Facilitating the negotiation of content for agreements with other US agencies and foreign and domestic organizations
- In collaboration with the PS, Program Office MM, and PI, finalizing development of the Project's PLRA and preparing it for formal negotiation and final agreement
- Participating in annual budget submission reviews with the Program Office
- Assessing Project technical, schedule, and cost performance and recommending course corrections to Directorate management
- Coordinating SMD concurrence on chair, membership, and the Terms of Reference (ToR) for Standing Review Board (SRB) independent reviews
- Coordinating with the MM to ensure the clear understanding of programmatic direction between SMD and the Program Office
- Preparing launch approval documentation (National Environmental Policy Act (NEPA) materials, contingency plans, approval letters, etc.)
- Resolving Project issues through the ESSP Program Office
- Coordinating program and Project issues with other involved SMD division and with HQ Functional offices

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#### *1.5.4.2 Program Scientist(s) for ESSP Projects*

The PS(s) reside in the ESD of SMD. Their roles and responsibilities are discussed in general in SMD Handbook. For the ESSP Program, these include but are not limited to:

- Managing the selection process, including definition, timing, preparation, and issuance of solicitations; pre-proposal conferences; scientific and technical reviews of submitted proposals; and preparation for selection of ESSP investigations
- Developing the scientific strategy, goals, and objectives for the ESSP Program solicitations
- Serving as the primary ESSP science spokesman and the primary interface with customers, stakeholders, and external elements for scientific objectives and accomplishments
- Assessing Project status against Level 1 science requirements and mission success criteria
- Monitoring and regularly reporting science-related issues to NASA
- Regularly updating NASA and the broad community on mission science results
- Working with the PI to document completion of science objectives
- Chartering program science working groups as required
- Maintaining traceability of completed program science objectives
- Assembling and releasing solicitations and supporting documentation—assisted by the PE and SOMA
- Managing the down-select process, when required, including Concept Study Kickoff, scientific and technical reviews, and preparation for down-select of ESSP investigations
- Collaborating with the Program Executive, ESSP Program Office, and the PI on the generation of the PLRAs, particularly the Level 1 Requirements
- Monitoring the impact of proposed mission changes on the Level 1 Requirements
- Maintaining regular contact with the PI

The tables in Appendix R clarify the functional assignments where ESD and Program Office personnel have similar responsibilities.

#### 1.5.5 ESSP Project Formulation, Approval, Baseline Review and Termination Processes

The ESSP Project Formulation, Approval, and Termination Process comply with the requirements of NPR 7120.5 (or 7120.8 as appropriate), *NASA Systems Engineering Processes and Requirements* (NPR 7123.1), and the *Policy for NASA Acquisition* (NPD 1000.5).

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While the ESSP Program Office may determine that the typical NPR 7120.5 project review and approval process requires tailoring to appropriately address the sub-orbital projects, these projects still require reviews and approval decisions.

#### *1.5.5.1 Formulation Process*

The purpose of project formulation is to complete the concept, technology development, and preliminary design. Formulation consists of two sub-phases, referred to as Phases A and B. ESSP Projects are primarily awarded through the AO/NRA process. When a project is selected, the project enters into Phase A if it is a one-step process. The two-step selection process makes final awards at the end of step-two, after which the awarded project enters into Phase B.

The SMD initiates a directed mission's official entry into formulation by releasing a project Formulation Authorization Document (FAD) and proceeding in accordance with NPR 7120.5. The Program Office supports the development of the FAD. Once the SMD AA signs the project FAD, the directed project formally enters formulation.

#### *1.5.5.2 Approval Process*

The project's implementation phase starts only after successfully passing KDP C. When the project indicates readiness to enter into implementation, the ESSP Program Office requests an independent assessment of the project's readiness. The approval to proceed into implementation marks the point at which NASA makes an external commitment to the cost, schedule, and performance of the mission. These commitments are clearly defined in the PLRA.

KDP's D, E, and F follow the same process as the previous life cycle gates.

#### *1.5.5.3 Baseline Review and Termination Processes*

The Program Office conducts periodic assessments of project performance. If an assessment is made that the project cannot meet the commitments at any point during Phase B through E, then the outcome of the assessment will be a recommendation to ESD for rebaselining, termination review, or continuation of the project.

If pursuit of a Termination Review is deemed appropriate, the ESSP Program Office and the project proceed in accordance with NPR 7120.5 and *Notification of Intent to Decommission or Terminate Operating Space Systems and Terminate Missions* (NPD 8010.3) in the case of operating missions. In any event, the outcome shall be documented in a Decision Memorandum and reviewed with the AA prior to final implementation.

## **1.6 Implementation Approach**

The ESSP Program comprises independent orbital and sub-orbital projects, uncoupled from one another in design, hardware, operations, and science objectives. Consistent with the Acquisition Strategy (Section 3.4 of this Plan), investigations are primarily selected through a competitive solicitation process by SMD with support from SOMA. The Program's acquisition strategy emphasizes the regular and frequent release of open and competitive solicitations. The ESSP Program seeks to contain project-level costs through the control of design, development, and



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operational costs. The ESSP Program Office does not conduct major acquisition activities (such as engineering design studies, hardware and software development, and mission and data operations support) or studies supporting make-or-buy decisions, since these activities are all performed only at the project level.

NASA SMD has the authority to release an ESSP solicitation and commission evaluation of the proposals. The SMD AA is the selecting official and must approve a project's transition to each subsequent life cycle phase. Teaming and partnering arrangements are encouraged. The solicitation selection of a PI-led team provides the full authority necessary to contract with all members of the team without further competition. Partner involvement and specific levels of partner contributions are documented in agreements listed in the respective Project Plans.

SOMA supports the selection of ESSP investigations through a fully-open and competitive process. Investigation teams are led by a single PI, with participation open to all categories of organizations, both foreign (on a no exchange of funds basis) and domestic, including educational institutions, industry, nonprofit organizations, NASA centers, FFRDCs, and other government agencies. For PI-led projects, the PI forms a team from any combination of these institutions.

At the Phase D to E transition point, orbital projects often undergo a transition from a development focus to a flight operations focus, and a change in management oversight. The projects should revise their Project Plan at this point to reflect any new management structure, the new budget, revised reporting, and focus on new procedures and requirements.

PIs must employ management processes, procedures, and methods that comply with NASA policies and procedures. Projects must document their management approach in their respective Project Plans. The Program Office convenes "Pause and Learn" sessions to share Lessons Learned and best practices, and to incorporate these into the project-level management, design, testing, and operational processes.

ESSP Projects follow the implementation policies and practices cited in the Internal Task Agreement (ITA), grant, task, or contract Statement of Work (SOW); these are based on Center or Agency procedures, or both. The ESSP Program Office negotiates the procedures to be cited in the ITA, grant, or contract SOW and implemented with project management.

ESSP Projects are independently proposed and competitively selected PI-led investigations addressing Earth Science themes under a common program funding/management structure. The program requirements in this section are flowed into the acquisition process via solicitations used to select investigations. After project selection, project-specific programmatic requirements (referred to as Level 1 Requirements) are set forth in a PLRA document and approved by the ESSP PM, the implementing Center director and the SMD AA. The PLRAs for the current projects are in Appendices G through P of this Program Plan.

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## 2.0 PROGRAM BASELINE

### 2.1 Requirements Baseline

The Program Commitment Agreement (PCA) for the ESSP Program defines the commitment that the SMD AA makes to the NASA Associate Administrator for the execution of the Program. The ESSP Program Hi-Level Requirements are:

- 1) The ESSP Program shall select and complete missions commensurate with the confirmed and approved mission cost cap.
- 2) ESSP Projects shall use a cost-effective, domestic, flight proven Expendable Launch Vehicle (ELV), unless specifically directed otherwise by NASA. Each ESSP AO or NRA describes the launch vehicle details or appropriate access to space. SMD provides access to space and launch vehicle funding and suborbital platforms. These funds are part of the total cost cap for each mission (except EV-I). Foreign launch vehicles may be utilized only if contributed by the foreign organization (on a no-exchange-of-funds basis) and the launch vehicle meets NASA quality and reliability standards.
- 3) For each orbital project, the primary planned launch date shall be within the time period specified by the associated AO.
- 4) For each suborbital investigation, flight operations shall be determined by science objectives and be completed within the timeframe specified in the solicitation.

Key Performance Parameters (KPPs) and outcomes that represent measures of success for the ESSP Program are:

- 1) Approval for Projects to proceed to Implementation at KDP C.
- 2) Achievement of the threshold science performance criteria as established in the PLRA for each operating mission.
- 3) Delivery of mission science data, meeting latency and performance objectives for each approved science data system during primary mission phase.

The assessment of the Program performance is conducted at Program Implementation Reviews and during project reviews.

#### 2.1.1 Project Requirements Baseline

ESSP Projects are independently proposed and competitively selected PI-led investigations addressing Earth Science themes under a common program funding/management structure. The program requirements in this section are flowed into the acquisition process via solicitations used to select investigations. After proposal selection, project-specific programmatic requirements (referred to as Level 1 Requirements) are set forth in a PLRA document and approved by the ESSP PM, the implementing Center director and the SMD AA. The PLRAs for the current

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projects are in Appendices G through P of this Program Plan. Table 2-1 identifies sources of requirements for ESSP Projects typically included in the solicitation used to select the investigation.

**Table 2-1: ESSP Requirements Sources**

| Type Requirement                                       | Where Created | Where Documented | Applicable to      | Compliance Verified By | Conduit to Performer |              |         |     |              |
|--|---------------|------------------|--------------------|------------------------|----------------------|--------------|---------|-----|--------------|
|  |               |                  |                    |                        | Solicitation         | Contract SOW | NPD NPR | PCA | Program Plan |
| Programmatic (Level 1)                                 | HQ            | Program Plan     | Individual Project | HQ/ Program            | -                    | -            | -       | -   | √            |
| Program High-Level                                     | HQ            | Program Plan     | Program            | HQ                     | -                    | -            | -       | √   | √            |
| Management Process                                     | HQ            | HQ NPD/ NPG      | Program            | HQ                     | -                    | -            | √       | -   | -            |
| Management Process                                     | HQ            | HQ NPD/ NPR      | All Projects       | Center                 | √                    | √            | √       | -   | -            |
| Center Management Process                              | Center        | Center           | All Projects       | Center                 | √                    | √            | -       | -   | -            |
| All requirements trace back to the NASA Strategic Plan |               |                  |                    |                        |                      |              |         |     |              |

The following sections specify programmatic requirements levied on all ESSP Projects.

#### *2.1.1.1 Project Science Requirements*

ESSP Projects shall achieve their science requirements while meeting their project-specific cost cap, as specified in their PLRA. The PLRA documents the baseline and the threshold science requirements based on the selected proposal and according to the following definitions:

- Baseline Science Requirements - That mission which, if fully implemented, accomplishes the entire set of scientific objectives identified at the initiation of the mission.
- Threshold Science Requirements - The minimum scientific requirements below which the investigation is not considered justifiable for the proposed cost. Threshold science requirements are also referred to as minimum science requirements or science floor.

The PI may recommend descoping the project-level science requirements from the baseline to the threshold science requirements in incremental fashion as delineated in the approved proposal or Concept Study Report. These descopes are a means for mitigating cost and schedule risks associated with cost-caps and are documented in an update to the PLRA. Projects without significant descope options during formulation and implementation may be considered to be higher risk. The ESSP PM, implementing Center Director, and SMD AA shall approve any descope before that option is exercised.

#### *2.1.1.2 Project Cost Requirements*

All ESSP Projects are cost-capped at a level defined in the applicable solicitation. The cost cap is established through the proposal and formulation process and formally documented at KDP C.

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The cost cap shall apply to the full life cycle cost (LCC) for all elements needed by the investigation. The solicitation will identify whether launch vehicle costs will be included in the cost-cap.

The cost cap shall include all Project-held reserves. Each Project is required to show a budget reserve posture at the end of phase B commensurate with the risk associated with implementation. Typically, the overall budget reserve posture is no less than 25% of cost-to-go through the end of Phase D, excluding the cost of the launch vehicle. An appropriate cost reserve for Phase E shall also be included.

Current approved NASA accounting practices shall be used in developing the total cost.

#### *2.1.1.3 Project Verification and Validation*

Individual Projects shall verify performance of ESSP orbital, sub-orbital, and ground elements through a combination of analysis, inspection, demonstration, similarity, and test, with particular emphasis on incremental, integrated, and concurrent testing. For orbital missions, the launch vehicle supplier shall be responsible for physical integration of the spacecraft with the launch vehicle and for verification of system integrity. For sub-orbital missions, the aircraft provider shall be responsible for the physical integration of the payload and for verification of system integrity. The Project shall be responsible for the end-to-end flight/ground system performance verification, preferably by test, rather than by analysis.

#### *2.1.1.4 Project Implementation Requirements*

Each Project shall develop a unique Project Plan, based on NPR 7120.5 or 7120.8 as appropriate, that defines the implementation approach. Implementation requirements specific to ESSP Projects are found below.

As applicable, Earned Value Management (EVM) shall be implemented for the Phase C and D development activities of all ESSP Projects, as required by NPR 7120.5 and *Earned Value Management* (NPD 9501.3). Due to their low total life cycle cost, EVM is not required for ESSP sub-orbital Projects.

Each ESSP Project shall have an effective SMA program as required by *NASA Policy for Safety and Mission Success* (NPD 8700.1) and document it in its Project SMA Plan. Section 3.2 addresses project-level SMA requirements. Projects that reside at institutions that currently have a NASA-approved SMA program may utilize their own institutional practices.

Each ESSP Project shall prepare a science data management plan for approval by the PI and the assigned PS. The PI is responsible for collecting the scientific, engineering, and ancillary information necessary to validate and calibrate the scientific data, analyzing the data to meet the proposal science objectives, delivering the data and data products to an appropriate data repository, publishing scientific findings, arranging the public release of data and data products, and communicating the results to the public. Each PI shall manage all data produced in accordance with ESD Data and Information Policy, available at <http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/>.

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Each ESSP Project shall prepare a final report within three months of the end of the prime mission, documenting the status of the Level I requirements, identifying how science and technical requirements have been met by the execution of the mission.

Any new technology transfer, exchange, or partnership agreements for ESSP Projects shall comply with all laws and regulations regarding export control and the transfer of sensitive proprietary technologies, including the requirements of *NASA Export Control Program* (NPR 2190.1) and the provisions of 22 CFR International Traffic In Arms Regulations (ITAR).

### 2.1.2 ESSP Requirements Traceability

The project selection process ensures alignment of ESSP Program and Project requirements to those handed down from the Agency and SMD. Successful accomplishment of ESSP Project Level 1 Requirements yields science data that address NASA Strategic Outcome 2.1. Table 2-2 traces ESSP Projects, and by extension their associated requirements, to the Earth Science Research Program Science Focus Areas. All ESSP Projects support Strategic Objective 2.1.7—to “enable the broad use of Earth system science observations and results in decision-making activities for societal benefits.”

**Table 2-2: Programmatic Requirement Traceability**

| NASA Strategic Objective    | 2.1.1                   | 2.1.2   | 2.1.3                       | 2.1.4                  | 2.1.5                          | 2.1.6                      |
|-----------------------------|-------------------------|---------|-----------------------------|------------------------|--------------------------------|----------------------------|
| Focus Area→<br>Project<br>↓ | Atmospheric Composition | Weather | Carbon Cycle and Ecosystems | Water and Energy Cycle | Climate Variability and Change | Earth Surface and Interior |
| GRACE                       |                         |         |                             |                        |                                | X                          |
| CloudSat                    | X                       |         |                             | X                      |                                |                            |
| CALIPSO                     | X                       |         |                             | X                      |                                |                            |
| Aquarius                    |                         |         |                             | X                      | X                              |                            |
| OCO-2                       | X                       |         | X                           |                        | X                              |                            |
| AirMOSS                     |                         |         | X                           |                        |                                |                            |
| ATTREX                      | X                       |         |                             | X                      | X                              |                            |
| CARVE                       | X                       |         | X                           |                        | X                              |                            |
| DISCOVER-AQ                 | X                       |         |                             |                        |                                |                            |
| HS3                         |                         | X       |                             |                        |                                |                            |

## 2.2 Work Breakdown Structure Baseline

The ESSP Program is uncoupled and therefore does not implement a program-level Work Breakdown Structure (WBS) baseline. ESSP Projects each develop and implement a customized WBS structure that best fits their organizational approach and mission design concept.

## 2.3 Schedule Baseline

The ESSP Program Office develops and maintains a master schedule (see Appendix D) that provides a snapshot of the current ESSP Program and Projects’ top-level milestones. This

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schedule is updated when the Program Plan is updated. ESD evaluates program schedule performance.

Each ESSP Project develops and maintains its own integrated master schedule, including all critical milestones, major events, and Agency and project-level reviews throughout the life cycle. These schedules identify any interdependencies for the critical milestones and the critical paths and are tied to the resources required to complete each task and meet critical milestones.

## **2.4 Resource Baseline**

The ESSP Program comprises independent, uncoupled science missions that are primarily the result of a competitive selection process. Program resource and workforce levels adjust in accordance with the solicitation plan, which is based upon program budget constraints and the investigation selection rate. Table E-1 contains the ESSP Program budget included in the most recent President's Budget request. Table E-2 provides the Program Office workforce plan to support fulfillment of programmatic responsibilities. The total budget is updated annually as part of the NASA PPBE process. ESD Resources Management provides ESD's guidance for developing the multi-year ESSP budget request. Each ESSP Project is responsible for the development of its own PPBE budget request. The ESSP Program Office conducts PPBE budget reviews with each Project Manager to ensure that the budget request is aligned with the remaining scope and the ESD guidance.

LaRC provides facility, administrative, and technical infrastructure to support the ESSP Program Office. Individual Projects are provided with facility, administrative, and technical infrastructure by the NASA Center or institution that serves as their host. Infrastructure requirements for acquisition, real property/facilities, aircraft, personal property, and information technology (IT) are fulfilled from existing capabilities.

## **2.5 Joint Cost and Schedule Confidence Level**

Because ESSP is an uncoupled program, program-level Joint Cost and Schedule Confidence Level (JCL) analysis and budgeting is not performed. When required, ESSP Projects perform a JCL analysis, which is used in formulating Agency internal and external financial commitments.

# **3.0 PROGRAM CONTROL PLANS**

## **3.1 Technical, Schedule, and Cost Control Plan**

The ESSP Program achieves its high-level requirements through the successful implementation of its projects. Each new ESSP Project is validated for compliance with ESSP Program requirements through three processes: the selection/acquisition process; the Project requirement development process; and the Project plan review and approval process.

Once an ESSP Project is selected for formulation, the ESSP Program Office provides frequent formal and informal communication with the projects to ensure continued compliance with ESSP Program requirements; timely identification of issues or areas of technical, schedule, or cost risk; and the application of appropriate mitigation or recovery activities.

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Drafted initially by the PI as part of the proposal, the PLRA documents ESSP program-level requirements specific to each Project (science requirements, launch timeframe, success criteria, and cost cap). After selection, a PE develops the PLRA in coordination with the MM, PS, and PI. The PLRA is signed no later than KDP-C.

The PI/Implementing Organization develops a unique Project Plan for each ESSP Project that tailors institutional processes and defines the implementation approach. The PM approves each ESSP Project Plan and concurs on the project-level stand-alone control plans.

### 3.1.1 Program Office Roles in Technical, Schedule, and Cost Performance Monitoring and Control

The MM is the primary POC for program insight into the technical, schedule, and cost status of each ESSP Project. Through regular formal and informal communication with the Project Manager/Principal Investigator, the MM maintains cognizance of the project performance against the project Integrated Master Schedule (IMS), cost cap, and performance requirements, as well as any emerging risks. The Program Office regularly reviews the status and projected ability of each project to meet its approved PLRA. The project plan documents the reporting and management processes. The MM utilizes the project's existing institutional processes and reviews (e.g., project's monthly and quarterly management status reviews), available EVM data for projects in Phase C/D development, and weekly teleconferences for project status updates to maintain cognizance of the project's performance while minimizing the impact on the project by not increasing the programmatic requirements.

The MM is supported by the ESSP Program Planning & Control Group in analyzing and evaluating the projects' performance. For additional insight and support, the MM collaborates with the ESD PE and PS, the ESSP CE, and SMA Lead. The ESSP MM may obtain expertise from NASA, academia, or industry to gain additional risk-based insight or oversight of a particular area for a Project. The Program Office risk-based assessment of ESSP Projects may occur throughout the Project life cycle.

### 3.1.2 Technical, Schedule, and Cost Performance Monitoring and Control Processes

The ESSP schedule includes program-level milestones for the projects. Monthly schedule status reviews are held to monitor the ESSP Master Schedule and track schedule performance. The control of project schedule milestones (KDPs, launch, etc.) is the responsibility of the ESSP Program and ESD. While the Program Office recommends changes to project Level 1 schedule milestones, the SMD AA approves the changes.

The project is evaluated for performance against the project IMS monthly and at scheduled life cycle reviews or special reviews as requested by the Program or SMD. The evaluation includes a detailed assessment of project schedules for overall implementation strategy and credibility, project budgets through prime mission operations and data analysis, and the approach for contractor/subcontractor management and coordination. ESSP makes recommendations to projects regarding the use of schedule margin as well as corrective actions, based on the Program Office analysis and assessments.

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ESSP Project budgets are initially estimated in the acquisition process as part of the original mission proposal and subsequent Concept Study Report. The total cost to NASA for all phases of an ESSP investigation, including the definition, development, launch service, mission operations (including communications costs) and data analysis, and reserves is included. Independent cost estimates and/or independent review boards may be used to verify estimates provided by the implementing organization at the discretion of the ESSP Program Manager.

Each project is required to show a budget reserve posture at the end of phase B, commensurate with the risk associated with the implementation of the mission, but typically no less than 25% of cost-to-go for costs through the end of Phase D (excluding the cost of the launch vehicle). An appropriate cost reserve for Phase E must be included. The PI and associated Project Manager have full discretion in applying the cost reserve in a given Fiscal Year within the approved project budget. Additional cost reserves may be held at ESD and not at the ESSP Program level. The ESSP Program Office recommends the disposition of any Program Unallocated Future Expenses (UFE) to ESD. Program Office analysis and assessments support recommendations to ESD and Projects regarding the use of reserves, as well as corrective actions. Cost control shall incorporate monthly tracking metrics such as reserve status, liens and encumbrances, reserve percentage of cost-to-go, obligations and commitments—plan versus actual, and labor—plan versus actual.

In accordance with NPR 7120.5, ESSP is not required to and will not implement EVM at the Program level. The ESSP Projects shall implement EVM for phase C/D scope, as required per NPR 7120.5, with the exception of the Earth Venture-1 investigations.

Table 3-1 lists the weekly, monthly, and quarterly reporting activities.



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**Table 3-1: ESSP Program Office Reporting**

| Report/Activity               | Content   | Customer                         | Frequency             | Format   |
|-------------------------------|---|----------------------------------|-----------------------|--|
| Program Office Standup Review | Program/Projects Status. Recent Events. Near-term activities. Technical, schedule, cost, and risk assessment review               | PM                               | Monthly               | Presentation, face-to-face meeting and telecon |
| CMC Status Review             | Program/Projects Status   | LaRC Center Director and CMC     | Monthly               | Face-to-face meeting with presentation         |
| Program Weekly Report         | Program/Projects Status (technical, schedule, cost and risk)  | ESD                              | Weekly                | Written report                                 |
| Project Tag-Up                | Project issues and status (technical, schedule, cost and risk)  | ESSP MM, PE                      | Weekly                | Teleconference                                 |
| Program Staff Meeting         | Program/Project status and issues, progress since prior week, activities to be performed during the current week and future weeks | Internal to ESSP Program Office  | Weekly                | Meeting with agenda, notes                     |
| Project Status Report         | Technical, cost, schedule and risk (greater detail for quarterly reviews)   | ESSP Program Office, SMD, Center | Monthly and Quarterly | Written report & presentation                  |
| Project Weekly Report         | Accomplishments for Week  | ESSP Program Office, PE          | Weekly                | Written report                                 |

### 3.1.3 Technical Excellence and Technical Authority Implementation

#### 3.1.3.1 *Technical Excellence*

ESSP Technical Excellence integrates the Program, Project, Engineering, and SMA personnel into a team that emphasizes cooperation and shared ownership regarding mission success. The Program Office facilitates technical excellence for a wide range of issues, which vary in complexity. For less complex issues, the Program CE may leverage subject matter experts (SME) at LaRC or other Centers and arrange for the SMEs to be available to the Program and Projects. For more complex issues, the Program CE may participate directly in Tiger Teams or may identify expertise for inclusion in the Tiger Team.

ESSP Projects typically have a Chief Engineer who serves as the Technical Authority for the project. The ESSP Program Office CE leverages Project CE capabilities to maintain a

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cognizance of the technical excellence activities within a project and exercise technical authority as appropriate. In the case where a Center or JPL has established an office that coordinates multiple project activities, the ESSP program CE would also maintain cognizance and exercise technical authority through that organization's CE in addition to the project CE. The ESSP Program Office CE collaborates and coordinates with the respective CEs to ensure Program Office perspectives are communicated across the ESSP Projects and supports the elevation of technical authority issues from a program perspective.

### 3.1.3.2 Technical Authority

A clear separation of programmatic and technical authority is maintained for the ESSP Program; each designated TA is organizationally and financially independent from ESSP programmatic path of authority. The engineering and SMA technical authorities for the ESSP Program are matrixed from and report directly to the LaRC Engineering (Figure 3-1) and SMA Directorates (Figure 3-2). The ESSP Program leverages and interfaces with the existing Health and Medical Authority (HMA) established at the Center that hosts each Project.

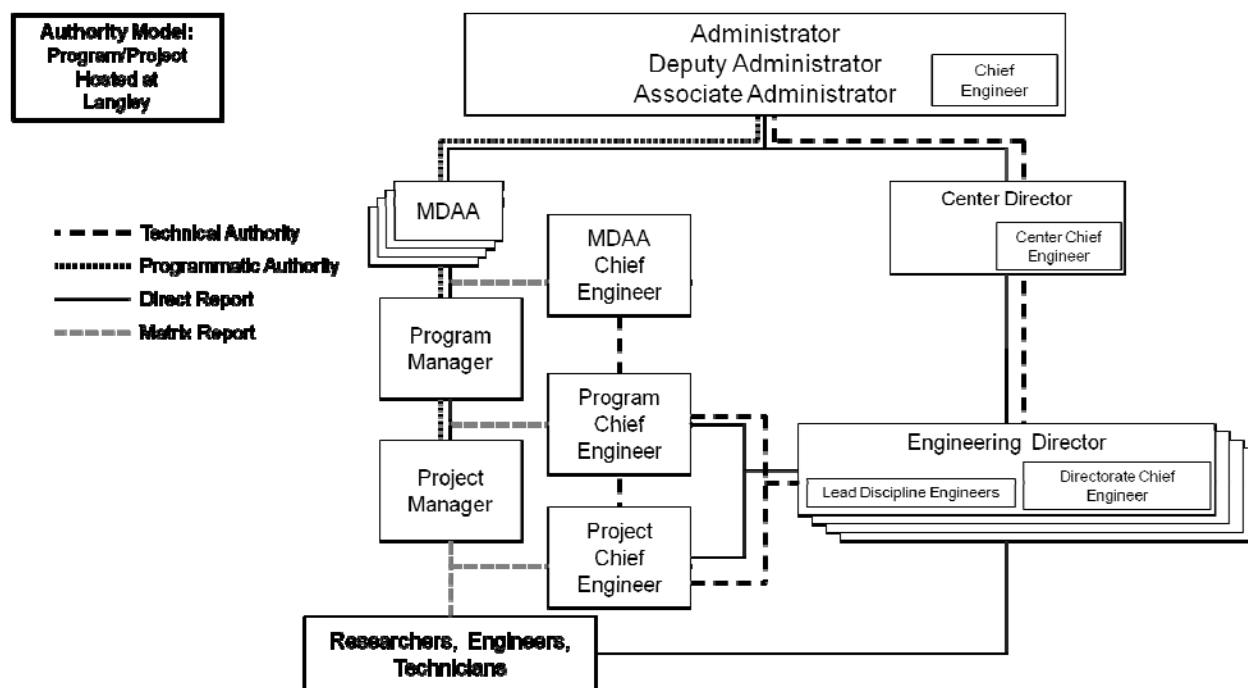
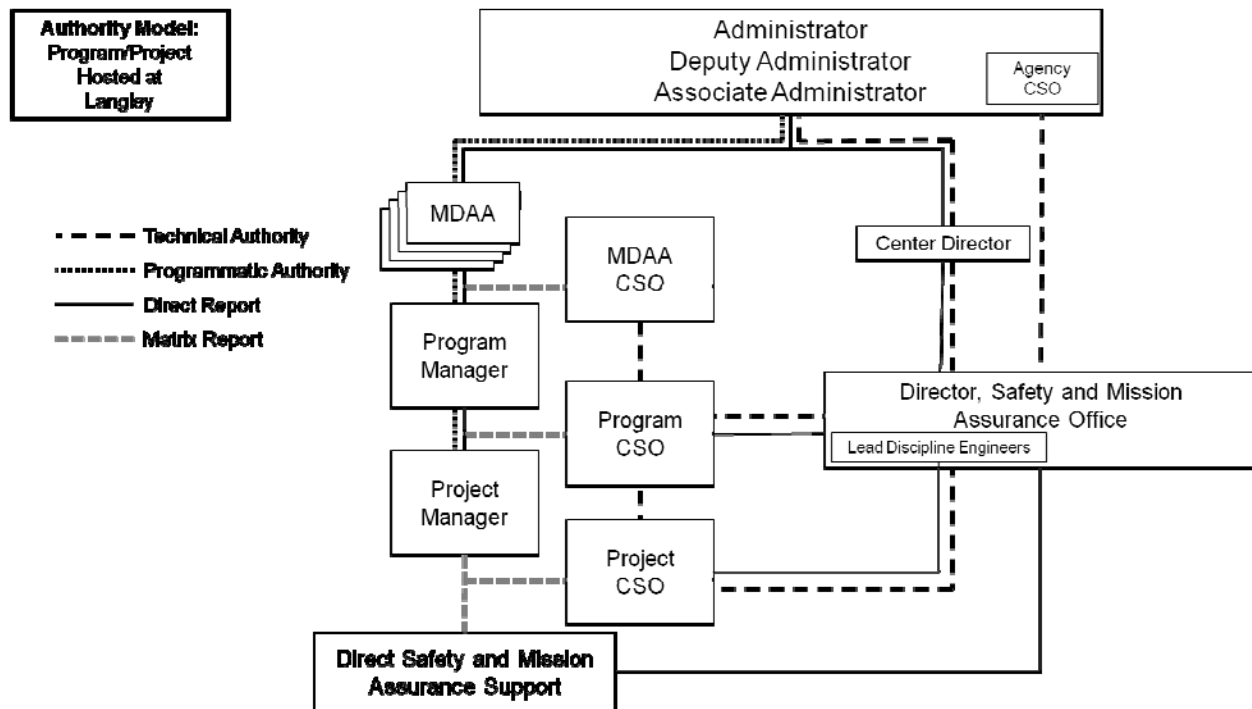


Figure 3-1: Flow of Engineering Technical Authority

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**Figure 3-2: Flow of SMA Technical Authority**

### 3.1.3.3 Tailors, Waivers, Deviations, and Dissenting Opinions

ESSP program-level and orbital project tailoring, waivers, deviations, and dissenting opinions adhere to the processes, forms, and authorities explicitly prescribed in *NASA Engineering and Program/Project Management Policy* (NPD 7120.4), NPR 7120.5, NPR 7123.1, and applicable Center policies and procedures. ESSP sub-orbital project tailoring, waivers, deviations, and dissenting opinions adhere to the processes, forms, and authorities explicitly prescribed in NPD 7120.4, NPR 7120.8, NPR 7123.1, and applicable Center policies and procedures. Projects develop necessary waivers in coordination with the Program Office. The Program Office ensures waivers are compliant with task agreements and programmatic guidelines, and coordinates with SMD to forward waiver request through responsible authorities. Waivers against Center practices do not require Directorate approval. Waivers against NPDs and NPRs are advanced by the ESD and the Directorate.

### 3.1.4 Performance Measures

The ESSP Program Office assesses its program performance in two ways: continuously against the Objectives set out in section 1.2 of this Plan and periodically through the conduct of Program Implementation Reviews (PIR).

The ESSP Program assesses the relevant project performance at key points in the project execution. The basis of assessment is documented in the Program Level Requirements Agreement (PLRA). The requirements are objective, quantifiable, and measurable, and traceable to the Program's five Key Performance Parameters (from section 2.1) and restated here:

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- 1) Confirmation for each Project approved for implementation;
- 2) Successful orbital launch or sub-orbital deployment and transition to operation of each Project in implementation;
- 3) Achievement of at least minimum success criteria for each operating mission;
- 4) Delivery of mission science data meeting latency and performance objectives for each approved science data system; and
- 5) Completion of mission life for each operating mission.

The project's PLRA documents the science requirements, mission and spacecraft performance, launch requirements, ground system requirements, mission requirements, and cost and cost management. If at any time during implementation of an ESSP project, the estimated cost-to-complete exceeds the firm mission cost cap, the project is subject to a termination review. For specific project performance measures, refer to the project PLRA in the appendices.

### **3.2 ESSP Safety and Mission Assurance Plan**

It is NASA's safety policy to protect the public, astronauts and pilots, NASA workforce, and high-value equipment and property from potential harm as a result of NASA activities and operations by providing safe programs, technologies, operations, and facilities; and to protect the environment. The ESSP Program is committed to supporting this policy by requiring all constituent Projects to adhere to NASA safety requirements during all phases of the life cycle.

The Program Office ensures that ESSP Projects implement thorough and robust SMA activities commensurate with the payload classification and/or risk classification. The goal of these SMA activities is to help ensure investigation success by applying safety, reliability, software assurance and quality NASA policies and procedures. This section of the Program Plan lists the governing documents from which project-level SMA Requirements are derived and the ESSP Program Office's role in implementing these requirements. Since all SMA activities are implemented at the project level, a program-level plan is not required.

The Program Office assesses the Projects' efforts to ensure that the Mission Assurance program being implemented is valid, complete, and effective. The focus of the Program's assessment will be the degree to which investigation success is enhanced by processes such as redundancy, management, configuration management, reliability analysis, fault protections, etc. The ESSP Program Office will ensure project-level compliance with SMA requirements by reviewing SMA plans that are stipulated in the solicitations, and by participating at project reviews. Participation at milestone reviews includes compliance checking on SMA deliverables and activities commensurate with the milestone being reviewed. Additionally, the ESSP Program Office supports the SMD in determining appropriate SMA requirements for inclusion in solicitations. The ESSP Program Office also supports scheduled NASA HQ Institutional Programmatic Support (IPS) reviews and ESSP Project audits (normally every three years at a Center level).

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The SMA requirements are based on a project SMA life cycle process perspective. Specific SMA disciplines are applied to each of these life cycle phases through application of the Agency SMA requirements. These applicable Agency documents, shown in Table 3-2, allow for tailoring processes and requirements based on the payload classifications and risk considerations.

**Table 3-2: Critical SMA Disciplines**

| Discipline  | Document No.     | Document Title   |
|---|------------------|--|
| Safety  | NPR 8715.3       | <i>NASA General Safety Program Requirements</i>                                |
| Quality Assurance   | NPD 8730.5       | <i>NASA Quality Assurance Program Policy</i>                                   |
|   | NPR 8735.2       | <i>Management of Government Quality Assurance Functions for NASA Contracts</i> |
| Compliance Verification, Audit, SMA Reviews, and SMA Process Maps | NPR 8705.6       | <i>Safety and Mission Assurance Audits, Reviews, and Assessments</i>           |
| Reliability and Maintainability                                   | NPD 8720.1       | <i>NASA Reliability and Maintainability (R&amp;M) Program Policy</i>           |
| Software Safety and Assurance                                     | NASA-STD-8719.13 | <i>NASA Software Safety Standard</i>   |
|   | NASA-STD-8739.8  | <i>NASA Software Assurance Standard</i>  |

To ensure compliance with all Occupational Safety and Health Administration (OSHA) and NASA SMA requirements, ESSP Projects are required to plan and implement a comprehensive Mission Assurance program for all flight and ground hardware, software, Ground Support Equipment (GSE), and mission operations early in formulation. This responsibility extends to all partners, prime contractors, subcontractors, and suppliers. Due to the uncoupled nature of the ESSP Program, the ESSP Program Office will not develop and manage a Closed Loop Problem Reporting and Resolution System as described in NPR 7120.5. Projects will utilize Problem Reporting, Analysis, and Corrective Action (PRACA) systems as prescribed by the implementing Center's requirements. For projects not completed at a NASA Center, equivalent practices will be allowed and documented in the project plan. The Program Office reviews PRACA systems for anomalies and non-conformances that have potential for causing similar issues on other ESSP Projects and communicate these appropriately.

For ESSP Projects that involve aircraft, an independent Airworthiness Safety Review shall be conducted for all aspects of the flight project, including mission operations, as specified by the aircraft host Center processes. Range Safety Review processes or Airworthiness Safety Reviews from organizations outside of NASA may be utilized if the sponsoring NASA Center approves such reviews. Requirements for an aviation safety program for each respective flight activity are set forth in *Aircraft Operations Management* (NPR 7900.3).

*NASA Procedural Requirements for Limiting Orbital Debris* (NPR 8715.6) requires routine conjunction assessments for all NASA orbital assets with maneuvering capability. The project management staff for each operational orbital payload will establish tasks and appropriate lines of communication with the Conjunction Assessment Risk Analysis (CARA) Program, located at Goddard Spaceflight Center (GSFC), for meeting this policy requirement and to communicate any indicated risks. Final plans, including demonstrations, should be implemented at least three

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months prior to launch. A foreign partner providing operational services must sign a standard CARA Non-Disclosure Agreement (NDA).

### 3.3 Risk Management Plan

*Agency Risk Management Procedural Requirements* (NPR 8000.4) requires the ESSP Program Office and each of the ESSP Projects to implement Continuous Risk Management (CRM) in order to perform Risk-Informed Decision Making (RIDM) consistent with the applicable provisions of NPRs 7120.5 or 7120.8. Each ESSP orbital Project is required to develop a stand-alone Risk Management Plan. Sub-orbital Projects are not required to have a stand-alone Risk Management plan, but will capture their risk management approach in their Project plans. Project Managers are expected to elevate to the Program Office those risks that have the potential to impact Program milestones or that require additional technical or programmatic resources beyond those available at their level.

The risk management plan for each ESSP Project will conform to NASA risk management requirements for all phases of the project life cycle. Projects may use their choice of risk management tools, provided these are consistent with the risk scoring, reporting, and format in NPR 8000.4. Each ESSP Project will identify risk areas conformant to the challenges encountered while executing requirements management, design and development, integration, and test activities under the constraints allocated by Project Level 1 Requirements as documented in Appendices G through P.

ESSP Projects are independent and will capture and manage their own risks. The primary risk management tools available are allocated schedule and financial reserves, technical performance modifications, and/or de-scoping of investigation requirements. Oversight and reporting is established to detect unmanageable risks that might threaten program or project-level baseline milestones, failures to meet KPPs or Level 1 Requirements, and dangerous trends that might threaten project success.

As part of the ESSP Program's risk management effort, the Program Office identifies and tracks Program Office risks, assesses significant project-level identified risks, concurrently with Projects, identifies risks that need to be elevated to the program level, and searches for cross-cutting programmatic risk areas that impact multiple ESSP Projects. The results of these activities form the basis for an overall implementation of RIDM at all levels of the organization. CRM at the program level includes RIDM recommendations to NASA HQ.

A Risk Management Board (RMB) addresses and mitigates risks tracked at the Program level. The RMB is chaired by the ESSP PM, is composed of the ESSP CE, ESSP Program Planning and Control Manager, the ESSP MMs, SMA, Program Office Risk Manager, technical experts and consultants, a facilitator/recorder, and is open to relevant organizations with an interest in the announced topics. Board membership is adjusted as dictated by program requirements. Appropriate project-level personnel may also attend as needed. The RMB members will review, validate, and potentially adjust the risk assessments established by the risk originator. The risk originator will initially be listed as the "Risk Owner," but the RMB may transfer the risk to another ESSP Program or Project team member for mitigation. If the RMB accepts the risk, it is

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placed into the Program's risk database and reviewed at least monthly. The risk database is posted on the NX server.

The *ESSP Program Risk Management Plan* (ESSP-0008) details the Program's risk management approach.

### **3.4 Acquisition Plan**

The ESSP acquisition strategy closely aligns with Program goals and objectives and enables the effective and efficient advancement of Agency, SMD and ESD needs, goals, and objectives. The ESSP Program acquisition strategy emphasizes the release of open and competitive solicitations during regular and frequent time intervals. The solicitation processes utilize peer review of the science content of the proposed investigations, as well as thorough independent review of their technical, management, and cost elements.

Solicitation development, proposal evaluation, and PI/investigation selection are the responsibility of SMD and are carried out to meet the requirements of the FAR and the NFS. The ESSP Program Office assists ESD and SOMA in defining the scope and strategy for the draft solicitation to ensure incorporation of Program requirements and Lessons Learned from current and previous projects. SOMA supports SMD solicitations and conducts Technical, Management, and Cost (TMC) evaluations of proposals generated as a result of these solicitations.

The ESSP Program Office does not participate in the evaluation of proposals, but observes the entire evaluation process in order to gain a greater understanding of any unique Project risks that should be monitored if the proposal is selected for implementation. Direct interaction between the ESSP Program Office and the proposed Project begins after selection. In all cases, clear and strict firewalls are established and implemented to mitigate any potential conflict of interest (whether real or perceived) that could affect the selection process.

ESSP agreements initiated at the program level are listed in Appendix F.

### **3.5 Technology Development Plan**

The ESSP Program and its constituent Projects are designed to use mature technology—Technology Readiness Level (TRL) 6 or higher. A Technology Development Plan is not required at the program level, because no hardware or software is developed. ESSP Projects are strongly encouraged to utilize mature and low-risk technologies. These technologies are typically matured through other technology development programs (e.g. ESTO's Instrument Incubator Program (IIP)), substantially reducing program- and project-level risk.

The ESSP Program interacts with the Office of the Chief Technologist (OCT) and ESTO to maintain awareness of technology investments and innovation across the Agency, as well as other government agencies, academia and the commercial aerospace community. Concurrently, ESSP identifies future needs and acceptable levels of risk with OCT and ESTO to increase their knowledge of ESSP activities and strategic direction in preparation for solicitation release.

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Interactions with these organizations assist the Program Office in keeping abreast of existing and emerging technologies, informing communications with prospective PIs and industry.

### 3.6 Systems Engineering Management Plan

The ESSP Program does not perform program-level system design and product realization processes, but does oversee the Projects' performance of these functions. As a result no Systems Engineering Management Plan (SEMP) is developed at the program level. The Program Office ensures project implementation of a SEMP that is commensurate with the payload classification and/or risk classification of the project.

### 3.7 Software Management Plan

There are no requirements for individual ESSP Projects to use common software, computer systems, methodologies, or tools. Additionally, the ESSP Program Office has no plans to develop custom software for purposes of managing its Projects. Therefore, there is no need for a program-level Software Management Plan (SMP).

The ESSP Program Office, however, is ultimately responsible for the success and quality of the total ESSP Program, which involves facilitating the successful implementation of constituent Projects—including software components and the related Software Engineering (SWE) activities employed—that meet all of their Level 1 Science Requirements within cost and resource constraints.

All ESSP Projects that are led by NASA organizations are subject to *NASA Software Engineering Requirements* (NPR 7150.2). This NPR is "self-tailoring." Based on the **Software Classification** and **Safety Criticality** of a project's *software containing systems*, a spreadsheet in the NPR determines the subset of the SWE requirements to be applied. Projects led by JPL organizations currently use JPL SWE procedures and standards that are essentially equivalent to those in NPR 7150.2.

In cases where ESSP Projects are implemented by academic, commercial, or other non-NASA organizations, aspects of Software Management (documents required, specific processes or standards to be used) will be defined by the contract SOW, which would reference applicable Agency and/or Center procedures. The ESSP Program Office would recommend the appropriate Agency and/or Center procedures to the Projects, and work with the project to define the applicable management practices, to be documented in the project plan and SOW.

When applicable, an ESSP Project develops an SMP, which details its plans for managing and developing its software products; the ESSP Program Office concurs with the contents of the SMP and any revisions prior to baselining.

### 3.8 Review Plan

The ESSP Program and its Projects participate in periodic reviews throughout their life cycles to assess performance and decide on continuation.



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### 3.8.1 Program-Level Approach

At the program level, a Standing Review Board (SRB) conducts an independent Program Implementation Review approximately every two years to validate conformance to the terms of the program requirements. The Terms of Reference (ToR) established for the review include gate products, success criteria, special assessments to be performed, and reporting of results. Because the ESSP Program is uncoupled and in its implementation phase, other typical life cycle reviews (Preliminary Design Review (PDR), Critical Design Review (CDR), etc.) are not applicable.

### 3.8.2 Program Approach to Project-Level Reviews

The ESSP Program Office works with the individual Projects to develop a review plan based on NPD 7120.4 and NPRs 7120.5, 7120.8 and 7123.1. For NASA-led Projects, the Program Office will coordinate its recommendations for the review chair and team members with the implementing Center and the ESD. For non-NASA led Projects (PI or Project Manager not hosted by a NASA Center), the Program Office will coordinate its recommendations for the review chair and team members with the implementing organization and LaRC, the ESSP Program host Center. In both cases, the convening authorities will approve the chair and review team members.

A ToR establishes reporting requirements for each project-level review. As a minimum for each review, the Review Chair submits an Executive Summary providing an assessment of the degree to which the success criteria was met and any outstanding critical deficiencies. For KDPs, the PM recommends to the SMD AA whether the project should enter the next phase of its life cycle.

At a minimum, orbital missions in Phase E must plan for the following formal reviews: Post-Launch Assessment Review (PLAR), bi-annual Senior Reviews, End of Prime Mission Review (EPMR), and Decommissioning Review (DR).

Section 1.5.5.3 describes the Termination Review process, including criteria.

## **3.9 Mission Operations Plan**

ESSP operations occur only at the project level, and each ESSP mission operates independently. Technical management processes are directed towards the successful operation of each independent project. No program-level Mission Operations Plan is required.

ESSP Missions operating within the Morning or Afternoon Constellations must ensure that the spacecraft can move safely out of the Constellation when desired or required. Performing this operation requires that the mission be part of the Constellation Contingency Procedures and the Constellation Operations Coordination Plan.

## **3.10 Environmental Management Plan**

There is no program-level Environmental Management Plan needed, since the NEPA checklist indicates that the Program Office performs no activities with potential environmental impact.

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ESSP Projects will prepare stand-alone Environmental Management Plans to comply with *Implementing the National Environmental Policy Act and Executive Order 12114* (NPR 8580.1) if activities indicate potential environmental impact. The Program Office assesses project-level activities associated with NPR 8580.1 and inserts any critical milestones associated with complying with NEPA regulations into the program schedule.

### 3.11 Logistics Plan

Development and operations occurs only at the project level, and each ESSP Project operates independently. No program-level Logistics Plan is required.

Integrated logistics management supporting development and operations activities occurs and is planned at the project level. The Program Office assesses scope and content of project-developed logistics plans, metrics, and reports for adequacy and conformance with policy directives. At a minimum, logistics planning will be assessed at formal milestone reviews.

Each ESSP Project will summarize its logistics plan in its Project Plan. If a stand-alone plan is required because of the detail and volume of material in the plan, it will comply with *Program and Project Logistics Policy* (NPD 7500.1).

### 3.12 Science Data Management Plan

The ESSP Program primarily oversees independent PI-led Projects. Each ESSP Project is responsible for all science-related aspects throughout the complete life cycle. Thus, there is no program-level Science Data Management Plan (SDMP).

Each ESSP Project will prepare an SDMP containing its plans related to management of all classes of science data. The initial version of the SDMP is written and baselined concurrently with other project-level document and control plans. The details of this plan should include description of tasks, staffing, schedules, software testing, software development (algorithms) required prior to beginning operations as well as data products development after beginning operations. Typically the SDMP is a stand-alone control plan, which is summarized in the Project Plan, and will address the approach for creating and releasing STI publications.

#### 3.12.1 Policies

The SDMP shows how a project plans to implement NASA policies regarding scientific openness, data-sharing, and timely dissemination of results, while preventing inappropriate release of Sensitive But Unclassified (SBU), proprietary, or export-controlled data.

The ESSP Program and its Projects comply with the NASA Earth Science Data and Information Policies, and Mission Data System Requirements. These can be accessed via <http://science.nasa.gov/earth-science/earth-science-data>.

The Data and Information Policy website also provides a common set of definitions and nomenclature to assist in complying with the Data & Information Policy. ESSP Projects are required to make use of the approved data system standards that apply to their science data systems and products.

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### 3.12.2 Science Data Processing Software Development

All project-level software developed for or by NASA—including software for science data processing, reduction, inversion, visualization, *etc.*—must comply with the SWE Requirements deemed applicable for that specific software effort. For NASA-led projects, NPR 7150.2 applies to Science Data Processing Software development regardless of whether it is governed by NPR 7120.5, NPR 7120.8, or another project management procedure. Section 3.7 of this Program Plan details how the Program Office will assess its Projects' software development performance.

### 3.12.3 Science Data vs. Information

The SDMP addresses processes and plans for two distinct classes of science data: "Science Data" and "Information." The distinction is important, because the two classes are governed by different agency documents and are archived separately by distinct organizations. (However, note that the term "data" is often used collectively to refer to both classes. In fact, this is how it is defined in the context of the Data & Information Policy.)

Science Data include raw and processed data sets that represent collections of measurements made by science instruments. These may be raw data counts, or values that have undergone calibration, geographical registration, or conversion to engineering units. Also included are higher level Science Data Products (SDPs) derived from the measurement data. This class includes the software, its documentation, and the ancillary, engineering, and other data required to recreate the various products, locate and subset data, read the files, and visualize and understand their contents. Science Data includes artifacts that would be submitted to a NASA DAAC.

Information is referred to by the Agency as "Scientific and Technical Information" (STI), which has a precise meaning:

*"the results (the analyses of data and facts and resulting conclusions) of basic and applied scientific, technical, and related engineering research and development."*

STI includes the scientific results that are published in peer-reviewed journals or released to public media and is governed by *Management of NASA Scientific and Technical Information* (NPD 2200.1) and by *Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information* (NPR 2200.2). All STI is archived in the NASA Aeronautics and Space Database (N&ASD). The subset of STI that is not restricted or limited in any way is released to the general public via the NASA Technical Reports Server.

## **3.13 Information and Configuration Management Plan**

### 3.13.1 Configuration Management

The *ESSP Program Configuration and Data Management Plan* (ESSPPO-0002) defines the requirements and processes for identification/definition, preparation, control, and disposition (storage, access, and records) of the non-scientific ESSP Program data. Change control for the ESSP Program and Project documentation is consistent with NASA change control policies and

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procedures, in order to enable visibility into all interactions and interdependencies within the Program.

ESSP Projects will manage all non-scientific data, including IT assets, in a cost-effective manner that ensures an appropriate level of integrity, confidentiality, and availability of information. They will follow Agency and Center policies, procedures, and requirements to protect NASA information and IT systems in a manner that is commensurate with the sensitivity, value, and criticality of the information.

### 3.13.2 Electronic Library

An electronic document library provides the ESSP Program Office an interactive way to collaborate, view, and archive information in a secure manner. The ESSP Program Office Configuration/Data Manager updates and maintains an electronic document library and membership.

The ESSP Program Office utilizes a document library that operates behind the LaRC firewall (known as NX) for internal and business related documentation. SBU documents uploaded to NX must indicate their sensitivity via metadata and document markings in accordance with ESSPPO-0002:

- Include the sensitivity explicitly in the Title field and/or the Summary field
- Select *Sensitive But Unclassified* or *ITAR/EAR* in the Access Constraint field

### 3.13.3 Lessons Learned

The ESSP Program Office takes a “Pause and Learn” approach, gathering lessons learned after major events such as reviews or solicitations or at a minimum frequency of every six months. The Configuration/Data Manager captures the ESSP Program Office’s lessons learned using requirements established by documentation in accordance with NPD 7120.4 and as described in *Lessons Learned Process* (NPR 7120.6).

The ESSP Program Office conducts forums, workshops, and project reviews to share lessons learned. MMs disseminate the lessons learned to each Project through day-to-day meetings and reviews as well as special lessons learned discussions at the start of each development phase.

### 3.13.4 Knowledge Capture

The ESSP Configuration/Data Manager Program Office captures lessons learned from the Program Office as well as those forwarded by the ESSP Projects and adds them to the electronic library.

## 3.14 Security Plan

The ESSP Program Office implements plans to address security, technology protection, and emergency response requirements.

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### 3.14.1 Security Requirements

The ESSP Program is committed to a safe and secure work environment, to ensuring that property is protected from vandalism, illegal intrusion, theft, and fire, that personnel are protected from injury, and that appropriate investigations are carried out, and findings are coordinated with designated management and law enforcement organizations. The ESSP Program Office adheres to *NASA Security Program Procedural Requirements* (NPR 1600.1) and *NASA Security Policy* (NPD 1600.2) and works with the LaRC Chief of Security (CCS) to verify adequacy of security implementation.

While the ESSP Program office does not store classified national security information (CNSI), it does handle SBU materials. As part of its information security implementation, the Program Office also follows *Information Security Program Management Procedures and Guidelines* (LPR 1620.1) in designating, identifying, marking, controlling, storing, accessing, disclosing, protecting, transmitting, and destroying SBU information when no longer needed. Industrial security pertains to contracts, grants, cooperative agreements, and other binding transactions in which performance shall require access to CNSI by the contractor, supplier, grantee, or its employees. The ESSP Program Office has no industrial security interfaces.

### 3.14.2 Information Technology Security Requirements

The ESSP Program adheres to *Security of Information Technology* (NPR 2810.1) and complies with the IT practices of *NASA Information Security Policy* (NPD 2810.1).

### 3.14.3 Emergency Response Requirements

The ESSP Program Office has no NASA Mission-Essential Infrastructure (MEI). Therefore, Emergency Response is limited to program documentation/information and personnel. All mission-essential program documentation/information is maintained electronically on NX, a central server which is backed up periodically and retained in accordance with *NASA Records Retention Schedules* (NPR 1441.1). Weather or facility related emergencies are announced by LaRC. For other types of emergencies, the ESSP Program Office follows the emergency policies and directives of LaRC. After normal duty hours, emergency instructions are provided through the news media. All emergency response processes and procedures are implemented in accordance with NASA emergency policies and requirements, including *NASA Continuity of Operations Planning (COOP) Procedural Requirements* (NPR 1040.1), *NASA Langley Research Center Emergency Plan* (LPR 1046.1), and *Continuity of Operations (COOP) Plan* (LPR 1040.3).

## 3.15 **Export Control Plan**

This Program Plan does not include a program-level Export Control Plan, since all export control activity occurs at the project level.

Each ESSP Project implements an export control process, compliant with the requirements of NPR 2190.1. Requirement compliance is flowed to the Projects through the solicitation process. Through this process, proposers are required to disclose and discuss any international

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participation, either through involvement of non-U.S. nationals and/or involvement of non-U.S. entities. The Program Office regularly monitors and reviews this activity at the project level to ensure its compliance with the NPR 2190.1.

### **3.16 Education and Public Outreach Plan**

Contributing to the enhancement of the quality of science, mathematics, and technical education and the public understanding of earth science are explicit goals of SMD and the ESSP Program. The ESSP Program is committed to informing the public and providing educational opportunities that support local, state, regional, and national educational objectives and reform efforts. The primary ESSP Program E/PO emphasis is at the project level. However, the ESSP Program also implements program-level education and public outreach aimed at raising public awareness and fostering collaboration between the Program and the Projects to increase the impact of project-level E/PO programs. The ESSP Program and Projects follow the *Policy and Requirements for the Education and Public Outreach Programs of SMD Missions* (SPD-18) [Appendix U] in the development of all E/PO activities.

ESSP Projects provide copies of periodic reports related to their E/PO activities and the SMD-approved E/PO Control Plan to the ESSP Program Office to support programmatic requirements. The ESSP will coordinate its E/PO activities with ESD and SMD E/PO activities.

### **3.17 End of Mission Plan**

The End of Mission Plan (EOMP) is not required at the program-level, because the Program itself does not operate orbital missions. All U.S internal orbital missions require a stand-alone plan, while EOMP requirements for missions with international partners are establish via a Memorandum of Understanding. Stand-alone EOMP's are described in NPR 8715.6 and is outlined in detail in *NASA Standard Process for Limiting Orbital Debris* (NASA-STD-8719.14). This NASA-STD has no automatic exclusions for any program or project due to limited funding, responsibility, or involvement of NASA in the program or project. If the mission is in the Morning or Afternoon Constellation, the EOMP must be coordinated with the Morning or Afternoon Constellation Mission Operations Working Group.

## **4.0 WAIVERS AND DEVIATIONS LOG**

The Program Plan contains a waiver log, located in Table 4-1, which is consistent with the requirements of NPR 7120.5.

To date, the Program Office has not initiated any waivers or deviations. Projects will document waiver that they initiated in their own Project Plans. The ESSP Program Office reviews these waivers and approves them on a case-by-case basis.

### Table 4-1: Waivers and Deviations Log

[illegible]

## 5.0 CHANGES LOG

The PM monitors NASA policies, directives, and requirements for changes affecting the ESSP Program. Updates required for key top-level program or project documentation are identified immediately, and generally included in annual updates. Table 5-1 documents Program Plan changes.

The PM annually evaluates the need for modifications of this Program Plan due to Project changes and other activities within the ESSP Program, or as driven by the above NASA documentation changes. The Program updates the PCA and applicable sections of this Program Plan whenever budget changes greater than 20 percent in a given year, or ten percent within a five-year horizon, occur.

### Table 5-1: Changes Log

[illegible]

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## Appendix A Acronyms and Abbreviations

|                               |  |
|-------------------------------|--|
| AA                            | Associate Administrator  |
| AAOES                         | Associate Administrator for the Office of Earth Science (GRACE)    |
| ACAM                          | Airborne Compact Atmospheric Mapper (DISCOVER-AQ)                  |
| ACI                           | Administratively Controlled Information                            |
| AGU                           | American Geophysical Union   |
| AIAA                          | American Institute of Aeronautics and Astronautics                 |
| AirMOSS                       | Airborne Microwave Observatory of Subcanopy and Subsurface         |
| ALERT                         | Acute Launch Emergency Reliability Tip                             |
| ANSI                          | American National Standards Institute                              |
| AO                            | Announcement of Opportunity  |
| APG                           | Annual Performance Goal  |
| APL                           | Applied Physics Laboratory (GRACE)                                 |
| ARC                           | Ames Research Center   |
| ASIC                          | Application-specific integrated circuit                            |
| ASM                           | Acquisition Strategy Meeting                                       |
| ASP                           | Acquisition Strategy Planning                                      |
| ATBD                          | Algorithm Theoretical Basis Document (OCO-2)                       |
| ATTREX                        | Airborne Tropical Tropopause Experiment                            |
| AVAPS                         | Airborne Vertical Atmosphere Profiling System (HS3)                |
| AWAS                          | Advanced Whole Air Sampler (ATTREX)                                |
| B-200                         | Designation for NASA King Air aircraft used for DISCOVER-AQ        |
| BARCA                         | Balanço Atmosférico Regional de Carbono na Amazônia (CARVE)        |
| BrO                           | Bromine oxide  |
| BrO <sub>3</sub> <sup>-</sup> | Bromate ion  |
| BRS                           | Baseline Requirement Set   |
| Cal/Val                       | Calibration/Validation   |
| CALIPSO                       | Cloud Aerosol LIDAR and Infrared Pathfinder Satellite Observations |
| CARA                          | Conjunction Assessment Risk Analysis                               |
| CARVE                         | Carbon in Arctic Reservoirs Vulnerability Experiment               |
| CBE                           | Current Best Estimate  |
| CCB                           | Configuration Control Board  |
| CCN                           | Contract Change Notice   |
| CCS                           | Center Chief of Security   |
| CD                            | Center Director  |
| CDM                           | Configuration/Data Manager   |
| CDR                           | Critical Design Review   |
| CE                            | Chief Engineer   |
| CEQ                           | Council on Environmental Quality                                   |
| CFO                           | Chief Financial Officer  |
| CH <sub>2</sub> O             | Formaldehyde   |
| CH <sub>4</sub>               | Methane  |
| CI                            | Configuration Item   |
| CIL                           | Critical Items List  |



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|                 |   |
|-----------------|---|
| CLIVAR          | Climate Variability (Aquarius)  |
| CM              | Configuration Management  |
| CMC             | Center Management Council   |
| CN              | Condensation Nuclei   |
| CNES            | Centre National d'Études Spatiales (CALIPSO)                                  |
| CNSI            | Classified National Security Information                                      |
| CO              | Carbon monoxide; Contracting Officer  |
| CO <sub>2</sub> | Carbon Dioxide  |
| COM             | Center of Mass (GRACE)  |
| CONAE           | Comisión Nacional de Actividades Espaciales (Aquarius)                        |
| COOP            | Continuity of Operations  |
| COTR            | Contracting Officer's Technical Representative                                |
| COTS            | Commercial-Off-The-Shelf  |
| CPL             | Cloud Physics LIDAR (ATTREX, HS3)   |
| CPU             | Central Processing Unit   |
| CRM             | Continuous Risk Management  |
| CS              | Civil Service   |
| CSA             | Canadian Space Agency; Configuration Status Accounting                        |
| CSO             | Chief Safety Officer  |
| CSR             | Center for Space Research; Concept Study Report                               |
| CSU             | Colorado State University (CloudSat)  |
| CY              | Calendar Year   |
| DA              | Decision Authority  |
| DAA             | Deputy Associate Administrator  |
| DAAC            | Distributed Active Archive Center   |
| DC-8            | NASA high altitude atmospheric research aircraft                              |
| Dev             | Developmental   |
| DFRC            | Dryden Flight Research Center   |
| DHC             | Designation of De Havilland aircraft (CARVE)                                  |
| Dir             | Directorate   |
| DISCOVER-AQ     | Air Quality Experiment  |
| DLH             | Diode Laser Hygrometer (ATTREX)   |
| DLR             | Deutsche Forschungsanstalt für Luft und Raumfahrt—German Space Agency (GRACE) |
| DMT             | Droplet Measurement Technologies (DISCOVER-AQ)                                |
| DOAS            | Differential Optical Absorption Spectrometer (ATTREX)                         |
| DoE ARM         | Department of Energy Atmospheric Radiation Measurement (CloudSat)             |
| DPAF            | Dual Payload Attach Fitting (CALIPSO/CloudSat)                                |
| DPMC            | Directorate Program Management Council  |
| DR              | Decommissioning Review  |
| DSCVR           | Deep Space Climate Observatory  |
| DSWG            | Data Systems Working Group  |
| DTM             | Dual Thruster Module (Aquarius)   |
| E/PO            | Education and Public Outreach   |
| EAC             | Estimate at Completion  |

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|         |   |
|---------|---|
| EAR     | Export Administration Regulation                  |
| EAV     | Experimental Aerospace Vehicles                   |
| ECHI    | Early Career Hiring Initiative                    |
| ECHO    | EOS Clearinghouse                                 |
| EDOS    | EOS Data and Operations System                    |
| EEE     | Electrical, Electronic, Electromechanical         |
| EESS    | Earth Exploration Satellite Service (Aquarius)    |
| EIA     | Electronics Industries Alliance                   |
| ELV     | Expendable Launch Vehicle                         |
| EMD     | Environmental Management Division                 |
| EMI     | Electromagnetic Interference                      |
| EOM     | End of Mission                                    |
| EOMP    | End of Mission Plan                               |
| EOS     | Earth Observing System                            |
| EPMR    | End of Prime Mission Review                       |
| ER-2    | NASA derivative of U-2 high-altitude aircraft     |
| ESD     | Earth Science Division; Electrostatic Discharge   |
| ESE     | Earth Science Enterprise                          |
| ESM     | Earth Systematic Missions                         |
| ESSP    | Earth System Science Pathfinder                   |
| ESSPPO  | Earth System Science Pathfinder Program Office    |
| ESTO    | Earth Science Technology Office                   |
| ETA     | Engineering Technical Authority                   |
| EV      | Earth Venture                                     |
| EVM     | Earned Value Management                           |
| EVMS    | Earned Value Management System                    |
| FAD     | Formulation Authorization Document                |
| FAR     | Federal Acquisition Regulation                    |
| FFRDC   | Federally Funded Research and Development Center  |
| FMEA    | Failure Modes and Effects Analysis                |
| FPGA    | Field-Programmable Gate Array                     |
| FRR     | Flight Readiness Review                           |
| FTA     | Fault Tree Analysis                               |
| FTS     | Fourier Transform Spectrometer (CARVE)            |
| FWHM    | Full Width at Half Maximum (CloudSat)             |
| FY      | Fiscal Year                                       |
| G, Y, R | Green, Yellow, Red                                |
| GCM     | General Circulation Model (CloudSat)              |
| GDS     | Ground Data System                                |
| GFZ     | GeoForschungZentrum (GRACE)                       |
| GH      | Global Hawk (RQ-4 drone)                          |
| GIDEP   | Government-Industry Data Exchange Program         |
| GOES    | Geostationary Operational Environmental Satellite |
| GOOS    | Global Ocean Observing System (Aquarius)          |
| GPMC    | Governing Program Management Council              |

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|                  |  |
|------------------|--|
| GOTS             | Government-off-the-shelf                                 |
| GPS              | Global Positioning System                                |
| GRACE            | Gravity Recovery and Climate Experiment                  |
| GSE              | Ground Support Equipment                                 |
| GSFC             | Goddard Space Flight Center                              |
| GSOC             | German Space Operations Center (GRACE)                   |
| H <sub>2</sub> O | Water  |
| HAIRS            | High Accuracy Inter-satellite Ranging System (GRACE)     |
| HAMSR            | High Altitude MMIC sounding radiometer (HS3)             |
| HDF              | Hierarchical Data Format                                 |
| HIRAD            | Hurricane Imaging Radiometer (HS3)                       |
| HIWRAP           | High-Altitude Imaging Wind and Rain Airborne Radar (HS3) |
| HMA              | Health and Medical Authority                             |
| HNO <sub>3</sub> | Nitric acid  |
| HQ               | Headquarters   |
| HS3              | Hurricane and Severe Storm Sentinel                      |
| HSRL             | High Spectral Resolution LIDAR (DISCOVER-AQ)             |
| HW               | Hardware   |
| IBPD             | Integrated Budget and Procurement Document               |
| ICA              | Independent Cost Analysis                                |
| ICE              | Independent Cost Estimate                                |
| ICR              | Investigation Concept Review                             |
| ID               | Identification   |
| IEEE             | Institute of Electrical and Electronics Engineers        |
| IFOV             | Instantaneous Field of View (CloudSat)                   |
| IIP              | Instrument Incubator Program                             |
| IIR              | Imaging Infrared Radiometer (CALIPSO)                    |
| ILS              | Integrated Logistic Support                              |
| IMOU             | International Memorandum of Understanding (GRACE)        |
| IMS              | Integrated Master Schedule                               |
| INVAP            | Argentine manufacturer of SAC-D spacecraft (Aquarius)    |
| IO               | Iodine monoxide  |
| IOC              | In-Orbit Checkout  |
| IPAO             | Independent Program Assessment Office                    |
| IPEP             | IV&V Project Execution Plan                              |
| IPS              | Institutional Programmatic Support                       |
| IPU              | Instruments Processing Unit (GRACE)                      |
| IR               | Infrared   |
| IRT              | Independent Review Team                                  |
| ISAA             | International Space Act Agreement                        |
| ISGA             | In situ Gas Analyzer (CARVE)                             |
| ISO              | International Standards Organization                     |
| I&T              | Integration and Test                                     |
| IT               | Information Technology                                   |
| ITA              | Internal Task Agreement                                  |

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|                  |   |
|------------------|---|
| ITAR             | International Traffic in Arms Regulations               |
| IV&V             | Independent Verification and Validation                 |
| JCL              | Joint Cost and Schedule Confidence Level                |
| JPL              | Jet Propulsion Laboratory                               |
| JSG              | Joint Steering Group (Aquarius)                         |
| KDP              | Key Decision Point                                      |
| KPP              | Key Performance Parameters                              |
| KSC              | Kennedy Space Center                                    |
| LAN              | Local Area Network                                      |
| LaRC             | Langley Research Center                                 |
| LCC              | Life Cycle Cost   |
| LI-COR           | Manufacturer of gas analyzer (DISCOVER-AQ)              |
| LIDAR            | Light Detection And Ranging                             |
| LLI              | Limited Life Item                                       |
| LLC              | Lessons Learned Committee                               |
| LLIS             | Lessons Learned Information System                      |
| LOA              | Letter of Agreement                                     |
| LPD              | LaRC Policy Directive                                   |
| LPR              | LaRC Procedural Requirements; Lawful Permanent Resident |
| LRR              | Launch Readiness Review                                 |
| LW               | Long Wave   |
| MCR              | Mission Concept Review                                  |
| MDAA             | Mission Directorate Associate Administrator             |
| MDR              | Mission Definition Review                               |
| MDRA             | Mission Definition and Requirements Agreement           |
| MEI              | Mission-Essential Infrastructure                        |
| Mgmt             | Management  |
| Mgrs             | Managers  |
| MM               | Mission Manager   |
| MMIC             | Monolithic Microwave Integrated Circuit (HS3)           |
| MMS              | Meteorological Measurement System (ATTREX)              |
| MOA              | Memorandum of Agreement                                 |
| MODIS            | Moderate Resolution Imaging Spectroradiometer (CALIPSO) |
| MOO              | Mission of Opportunity                                  |
| MOS              | Mission Operations System                               |
| MOTS             | Modified-off-the-shelf                                  |
| MOU              | Memoranda of Understanding                              |
| MRB              | Material Review Board                                   |
| MSFC             | Marshall Space Flight Center                            |
| MTP              | Microwave Temperature Profiler (ATTREX)                 |
| N <sub>2</sub> O | Nitrous oxide   |
| N&ASD            | NASA Aeronautics and Space Database                     |
| N/A              | Not Applicable; Not Available                           |
| NACI             | National Agency Check and Inquiries                     |
| NAR              | Non-advocate Review                                     |

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|                 |  |
|-----------------|--|
| NARA            | National Archives and Records Administration                     |
| NASA            | National Aeronautics and Space Administration                    |
| NDA             | Non-disclosure Agreement   |
| NEN             | Near Earth Network   |
| NEPA            | National Environmental Policy Act                                |
| NFS             | NASA FAR supplement  |
| NID             | NASA Interim Directive   |
| NO <sub>2</sub> | Nitrogen dioxide   |
| NOA             | New Obligation Authority   |
| NOAA            | National Oceanic and Atmospheric Administration                  |
| NO <sub>x</sub> | Nitrogen oxides  |
| NPD             | NASA Policy Directive  |
| NPR             | NASA Procedural Requirements                                     |
| NRA             | NASA Research Announcement                                       |
| NRC             | National Research Council  |
| NSS             | NASA Safety Standard   |
| NV              | Non-volatile (DISCOVER-AQ)                                       |
| NWP             | Numerical Weather Prediction (CloudSat)                          |
| NX              | LaRC Document Management System                                  |
| O <sub>2</sub>  | Molecular Oxygen   |
| O <sub>3</sub>  | Ozone  |
| OCE             | Office of Chief Engineer   |
| OCIO            | Chlorine dioxide   |
| OCO             | Orbiting Carbon Observatory                                      |
| OCT             | Office of Chief Technologist                                     |
| ODIN            | Outsourcing Desktop Initiative for NASA                          |
| OEPM            | Office of Education Program Management                           |
| OES             | Office of Earth Science  |
| OMB             | Office of Management and Budget                                  |
| ONERA           | Office Nationale d'Études et de Recherches Aérospatiales (GRACE) |
| Ops             | Operations   |
| ORR             | Operations Readiness Review                                      |
| Op              | Operational  |
| OSC             | Orbital Science Corporation                                      |
| OSHA            | Occupational Safety and Health Administration                    |
| OSMA            | Office of Safety and Mission Assurance                           |
| P-3B            | Designation of NASA Orion aircraft used for DISCOVER-AQ          |
| PA              | Program Analyst  |
| PA&R            | Programmatic Audit and Review                                    |
| PAL             | Programmable Array Logic   |
| PALS            | Passive Active L-band System (CARVE)                             |
| PAO             | Public Affairs Officer   |
| PART            | Program Assessment Rating Tool                                   |
| PB              | President's Budget   |
| PBMA            | Process Based Mission Assurance                                  |

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|         |   |
|---------|---|
| PCA     | Program Commitment Agreement  |
| PCRS    | Picarro Cavity Ring-Down Spectrometer (ATTREX)  |
| PDR     | Preliminary Design Review   |
| PE      | Program Executive   |
| PFP     | Programmable Flash Pack (CARVE)   |
| PI      | Principal Investigator  |
| PIR     | Program Implementation Review   |
| PLAR    | Post-Launch Assessment Review   |
| PLRA    | Program-Level Requirements Appendix   |
| PM      | Program Manager   |
| PMC     | Program Management Council  |
| POC     | Point of contact  |
| PODAAC  | Physical Oceanography DAAC  |
| POP     | Program Operating Plan  |
| PPBE    | Planning, Programming, Budgeting and Execution  |
| PRA     | Probabilistic Risk Assessment   |
| PRACA   | Problem Reporting, Analysis, and Corrective Action  |
| Proteus | High altitude long-endurance aircraft built by Scaled Composites (CALIPSO)                  |
| PS      | Program Scientist   |
| PSLA    | Project Service Level Agreement   |
| PSM     | Procurement Strategy Meeting  |
| PSR     | Program Status Review   |
| Q       | Yearly quarter  |
| R&A     | Research and Analysis   |
| R&M     | Reliability and Maintainability   |
| Reps    | Representatives   |
| Req.    | Requirements  |
| Rev     | Revision  |
| RIDM    | Risk Informed Decision Making   |
| RIS     | Risk Identification Sheet   |
| RLV     | Reusable Launch Vehicle   |
| RM      | Risk Management; Risk Manager   |
| RMB     | Risk Management Board   |
| RMD     | Risk Management Database  |
| RMP     | Risk Management Plan; Risk Mitigation Phase   |
| RMS     | Requirements Management System  |
| ROSES   | Research Opportunities in Space and Earth Sciences  |
| RR      | Radiance Research (DISCOVER-AQ)   |
| RSC     | United States Air Force Research, Development, Test & Evaluation Support Complex (CloudSat) |
| RSDO    | Rapid Spacecraft Development Office   |
| RSM     | Range Safety Manual   |
| SA      | Solar Array   |
| SAC-D   | Satélite de Aplicaciones Científicas (Aquarius)   |

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|                 |  |
|-----------------|--|
| SALMON          | Stand-Alone Mission of Opportunity Notice                      |
| SAP             | Software Assurance Plan  |
| SBU             | Sensitive But Unclassified                                     |
| SCaN            | Space Communications and Navigation                            |
| SCDS            | Space Communications and Data Systems                          |
| SCSW            | Safety Critical Software                                       |
| SDMP            | Science Data Management Plan                                   |
| SDP             | Science Data Product   |
| SDS             | Science Data System  |
| SEMP            | Systems Engineering Master Plan                                |
| SETA            | Security Education and Training, and Awareness                 |
| SF <sub>6</sub> | Sulfur hexafluoride  |
| S-HIS           | Scanning High-resolution Interferometer Sounder (HS3)          |
| SIR             | System Integration Review                                      |
| SMA             | Safety and Mission Assurance                                   |
| SMAO            | Safety and Mission Assurance Office                            |
| SMAP            | Soil Moisture Active and Passive (AirMOSS)                     |
| SMD             | Science Mission Directorate                                    |
| SME             | Subject Matter Expert  |
| SFMR            | Stepped Frequency Microwave Radiometer                         |
| SMP             | Software Management Plan                                       |
| SMSR            | Safety and Mission Success Review                              |
| SN              | Space Network  |
| SO <sub>2</sub> | Sulfur dioxide   |
| SoC             | System-on-a-chip   |
| SOMA            | Science Office for Mission Assessments                         |
| SOW             | Statement of Work  |
| SP              | Special Publication  |
| SPD             | SMD Policy Document  |
| SPIAD           | Science Pending International Agreements Database              |
| SR              | Senior Review; Status Review                                   |
| SRA             | Schedule Risk Assessment                                       |
| Sys.            | Systems  |
| SRB             | Standing Review Board  |
| SRR             | System Requirements Review                                     |
| SS/L            | Space Systems Loral (GRACE)                                    |
| SSFR            | Solar Spectral Flux Radiometer (ATTREX)                        |
| SSMAP           | Systems Safety and Mission Assurance Program                   |
| SSS             | Sea Surface Salinity   |
| SSTP            | System Safety Technical Plan                                   |
| STA             | Safety and Mission Assurance Technical Authority               |
| STD             | Standard   |
| STI             | Scientific and Technical Information                           |
| SuperSTAR       | High-precision accelerometer manufactured by ONERA/CNS (GRACE) |
| SW              | Software   |

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|                  |   |
|------------------|---|
| SWE              | Software Engineering  |
| S/P              | Spacecraft / Platform                                       |
| TA               | Technical Authority   |
| TBD              | To Be Determined  |
| TBR              | To Be Resolved; To Be Reviewed; To Be Revised               |
| TCCON            | Total Column Carbon Observing Network (OCO-2)               |
| TCSP             | Tropical Cloud Systems and Processes                        |
| TDRSS            | Tracking and Data Relay Satellite System                    |
| Tech.            | Technical   |
| TMC              | Technical, Management, and Cost                             |
| ToR              | Terms of Reference  |
| TPM              | Technical Performance Measure                               |
| TRL              | Technology Readiness Level                                  |
| TSGC             | Texas Space Grant Consortium (GRACE)                        |
| TTCP             | Technology Transfer Control Plan                            |
| TWiLiTE          | Tropospheric Wind LIDAR Technology Experiment (HS3)         |
| UAS              | Uninhabited Aerial System                                   |
| UAV              | Uninhabited Aerial Vehicles                                 |
| UAVSAR           | UAV Synthetic Aperture Radar (AirMOSS)                      |
| UCATS            | UAS Chromatograph for Atmospheric Trace Species (ATTREX)    |
| UFE              | Unallocated Future Expenses                                 |
| UHF              | Ultrahigh Frequency   |
| ULH              | UAS Laser Hygrometer (ATTREX)                               |
| USSTRATCOM       | US Strategic Command  |
| UTCSR            | University of Texas Center for Space Research (GRACE)       |
| URL              | Uniform Resource Locator                                    |
| V&V              | Verification and Validation                                 |
| VAFB             | Vandenberg Air Force Base                                   |
| VCL              | Vegetation Canopy LIDAR                                     |
| VHDL             | VHSIC Hardware Description Language                         |
| VHSIC            | Very-High-Speed Integrated Circuit                          |
| WB-57            | NASA aircraft used for high altitude missions               |
| WBS              | Work Breakdown Structure                                    |
| WFC              | Wide Field Camera (CALIPSO)                                 |
| WOCE             | World Ocean Circulation Experiment (GRACE)                  |
| WYE              | Work Year Equivalent  |
| X <sub>CO2</sub> | Column Average Carbon Dioxide Dry Air Mole Fraction (OCO-2) |



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## Appendix B References

### NASA POLICY DIRECTIVES

NM 7120-81, *NASA Interim Directive (NID) for NASA Procedural Requirements (NPR) 7120.5D*

NPD 1000.0, *NASA Governance and Strategic Management Handbook*

NPD 1000.5, *Policy for NASA Acquisition*

NPD 1600.2, *NASA Security Policy*

NPD 2200.1, *Management of NASA Scientific and Technical Information*

NPD 2810.1, *NASA Information Security Policy*

NPD 7120.4, *NASA Engineering and Program/Project Management Policy*

NPD 7500.1, *Program and Project Logistics Policy*

NPD 8010.3, *Notification of Intent to Decommission or Terminate Operating Space Systems and Terminate Missions*

NPD 8700.1, *NASA Policy for Safety and Mission Success*

NPD 8720.1, *NASA Reliability and Maintainability (R&M) Program Policy*

NPD 8730.2, *NASA Parts Policy*

NPD 8730.5, *NASA Quality Assurance Program Policy*

NPD 9501.3, *Earned Value Management*

### NASA PROCEDURAL REQUIREMENTS

NPR 1040.1, *NASA Continuity of Operations Planning (COOP) Procedural Requirements*

NPR 1441.1, *NASA Records Retention Schedules*

NPR 1600.1, *NASA Security Program Procedural Requirements*

NPR 2190.1, *NASA Export Control Plan.*

NPR 2200.2, *Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information*

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NPR 2810.1, *Security of Information Technology*

NPR 6000.1, *Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components*

NPR 7120.5, *NASA Space Flight Program and Project Management Requirements* (see also NM 7120-81)

NPR 7120.6, *Lessons Learned Process*

NPR 7120.8, *NASA Research and Technology Program and Project Management Requirements*

NPR 7123.1, *NASA Systems Engineering Processes and Requirements*

NPR 7150.2, *NASA Software Engineering Requirements*

NPR 7900.3, *Aircraft Operations Management*

NPR 8000.4, *Agency Risk Management Procedural Requirements*

NPR 8580.1, *Implementing the National Environmental Policy Act and Executive Order 12114*

NPR 8705.6, *Safety and Mission Assurance Audits, Reviews, and Assessments*

NPR 8715.3, *NASA General Safety Program Requirements*

NPR 8715.6, *NASA Procedural Requirements for Limiting Orbital Debris*

NPR 8735.2, *Management of Government Quality Assurance Functions for NASA Contracts*

## **NASA STANDARDS**

NASA-STD-8719.13, *NASA Software Safety Standard*

NASA-STD-8719.14, *NASA Standard Process for Limiting Orbital Debris*

NASA-STD-8739.8, *NASA Software Assurance Standard*

## **NON NASA STANDARDS**

ANSI/EIA 748-A, *ANSI Standard for Earned Value Management Systems*

## **NASA LANGLEY RESEARCH CENTER POLICY DIRECTIVES AND PROCEDURAL REQUIREMENTS**

LPR 1040.3, *Continuity of Operations (COOP) Plan*

LPR 1046.1, *NASA Langley Research Center Emergency Plan*

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LPR 1620.1, *Information Security Program Management Procedures and Guidelines*

## **ESSP PROGRAM OFFICE DOCUMENTS**

ESSPPO-0001, *ESSP Program Plan*

ESSPPO-0002, *ESSP Program Office Configuration Management Plan*

ESSPPO-0004, *ESSP Program Office Configuration Audit Plan*

ESSPPO-0006, *ESSP Program Office Significant Incident Reporting Procedure for ESSP Operations*

ESSPPO-0007, *Organizational Conflict of Interest Avoidance Plan*

ESSPPO-0008, *ESSP Risk Management Plan*

## **RELATED REFERENCES**

*2006 Earth Science Reference Handbook* (NP-2006-5-768-GSFC).

*2010 Science Plan: For NASA's Science Mission Directorate* (Science Plan), 2010.

*2011 NASA Strategic Plan*, 2011.

*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (Decadal Survey), 2007.

*Federal Acquisition Regulation* (FAR)

*International Traffic In Arms Regulations* (22 CFR 120-130)

*NASA Earth Science Data and Information Policy*

*NASA FAR Supplement* (NFS)

*NASA Systems Engineering Handbook* (NASA/SP-2007-6105, Rev1)

*Policy and Requirements for the Education and Public Outreach Programs of SMD Missions*, (SPD-18), January 28, 2010.

*Science Mission Directorate Management Handbook* (SMD Management Handbook), 2008.

## **WEB SITE REFERENCES**

ESSP Program Office. <http://science.nasa.gov/about-us/smd-programs/earth-system-science-pathfinder/>

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NASA Federal Acquisition Regulations (FAR) Supplement (NFS).

<http://www.hq.nasa.gov/office/procurement/regs/nfstoc.htm>

NASA Online Directives System (NODIS). <http://nodis3.gsfc.nasa.gov/>

NASA Science Earth Data & Information Policy. <http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/>

NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES).

<http://nspires.nasaprs.com/external/>

ScienceWorks. <https://scienceworks.hq.nasa.gov/>

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## Appendix C Glossary

**Acceptable Risk.** A risk that is well understood and agreed to by the program/project, organization partners, stakeholders, governing authority, mission directorate, and other customer(s) such that no further specific mitigating action is required to achieve the defined success criteria within the approved level of resources. Acceptable risk occurs when it is decided that no further expenditures are warranted for mitigating the risk and that no further action will be taken to reduce the risk's exposure.

**Access.** Access is the ability to do something with a computer resource. This usually refers to a technical ability (e.g., read, create, modify, or delete a file, execute a program, or use an external connection.)

**Acquisition Strategy Meeting (ASM).** A forum where senior Agency Management reviews major acquisitions in programs, projects, or activities before authorizing budget expenditures. The ASM is held at the Mission Directorate/Mission Support Office level, implementing the decisions that flow out of the Acquisition Strategy Planning (ASP) meeting and recommending implementation plans for approval.

**Acquisition Strategy Planning Meeting.** A forum that provides an early view of potential major acquisitions so that senior leaders can consider issues such as the appropriate application of new agency and Administration initiatives, current portfolio risk and implications to the future portfolio, high-level make-or-buy strategy and the placement of development or operations work in-house versus out-of-house. It also provides the strategic framework for addressing challenges associated with fully utilizing NASA Centers' capabilities, including workforce and infrastructure and shaping the Agency over time.

**Acquisition.** The acquiring by contract with appropriated funds of supplies or services (including construction) by and for the use of the Federal Government through purchase or lease, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated. Acquisition begins at the point when Agency needs are established and includes the description of requirements to satisfy Agency needs, solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling Agency needs by contract.

**Active Records.** Records that are referred to on a frequent basis, i.e., daily or weekly. Records that are maintained in office files for immediate access, use, and reference. Also considered current records, which are necessary for conducting the business of an office.

**Administratively Controlled Information (ACI).** Certain official information and material which is not national security information (and therefore cannot be classified), nonetheless, should be protected against disclosure. Such information and material, which may be exempt from disclosure by statute or is determined by a designated NASA official to be especially sensitive, shall be afforded physical protection sufficient to safeguard it from unauthorized disclosure (previously designated "For Official Use Only")

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**Agency Program Management Council.** The senior management group, chaired by the Associate Administrator or designee, responsible for reviewing program formulation performance, recommending approval of proposed programs, and overseeing implementation of designated programs and projects according to agency commitments, priorities and policies.

**Aggregate Risk.** The cumulative risk associated with a given performance measure, accounting for all significant risk contributors. For example, the total probability of loss of mission is an aggregate risk quantified as the probability of the union of all scenarios leading to loss of mission.

**Approval (for Implementation).** The acknowledgment by the DA that the program/project has met stakeholder expectations and formulation requirements, and is ready to proceed to implementation. By approving a program/project, the DA commits the budget resources necessary to continue into implementation. Approval (for Implementation) must be documented.

**Approval.** Authorization by a required management official to proceed with a proposed course of action. Approvals must be documented.

**Approved Manufacturer.** A manufacturer that has passed an audit intended to verify that a company has the manufacturing capability and implemented quality management system with controlled processes that will ensure that products meet the requirements of applicable specifications.

**Aquarius.** ESSP Project designed to measure Sea Surface Salinity.

**Ascending Node.** The point in the orbit where a satellite crosses the Earth's equatorial plane in passing from the southern hemisphere to the northern hemisphere.

**Assessment.** Review or audit process, using predetermined methods, that evaluates hardware, software, procedures, technical and programmatic documents and the adequacy of their implementation. The evaluation of a program, project, or institutional initiative with respect to its accomplishments and performance in meeting requirements.

**Assurance.** Providing a measure of increased confidence that applicable requirements, processes, and standards are being fulfilled. Grounds for confidence that the other four security goals (integrity, availability, confidentiality, and accountability) have been adequately met by a specific implementation. "Adequately met" includes (1) functionality that performs correctly, (2) sufficient protection against unintentional errors (by users or software), and (3) sufficient resistance to intentional penetration or bypass.

**A-Train or Afternoon Constellation.** A group of Earth-orbiting satellites with synergistic science objectives in similar sun-synchronous orbits and with the satellites distributed along the orbit in close proximity, such that they over-fly the same geographic region within seconds to minutes of each other. Their ascending node equator crossings are near 13:30 hours Mean local time. These satellites maintain their relative positions and control boxes by actively, but

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independently, maneuvering. Individual satellites remain in the “orbital train” so long as they maintain their assigned position in the train and are acquiring the required science measurements.

**Audit.** (1) an examination of records or financial accounts to check their accuracy, or (2) a systematic check or assessment, especially of the efficiency or effectiveness of an operation.

**Background Investigation.** The means or procedures used to determine the suitability of an individual to have privileged or limited privilege access and to hold a “Public trust.” Conducted by the Center chief of Security.

**Baseline (Document Context).** An agreed to set of requirements, designs, or documents that will have changes controlled through a formal approval and monitoring process. Implies the expectation of a finished product, though updates may be needed as circumstances warrant. All approvals required by Center policies and procedures have been obtained.

**Baseline (general context).** An agreed-to set of requirements, cost, schedule, designs, documents, etc. that will have changes controlled through a formal approval and monitoring process.

**Baseline Schedule.** The original approved plan plus or minus approved scope changes.

**Baseline Science Requirements.** The investigation performance requirements necessary to achieve the entire set of science objectives identified at the initiation of the mission. (Also see Threshold Science Requirements.)

**Case File.** A folder or other file unit containing materials relating to a specific action, transaction, event, person, place, project, or other subject. A case file may cover one or many subjects that relate to the case; for example, a contract file contains records on a specific contract, such as the application, correspondence, reports, and processing documents. Other types of case files include official personnel folders, surveys, and studies.

**Center Management Council (CMC).** The council at a Center that performs oversight of programs and projects by evaluating all program and project work executed at that Center.

**CloudSat.** An ESSP Project that observes vertical distribution of cloud systems and their ice and water contents.

**Commercial-Off-The-Shelf (COTS) Software.** Operating systems, libraries, applications and other software purchased from a commercial vendor. Not customized for a particular project. Access to source code and documentation are often limited.

**Commitment Baseline.** Establishes and documents an integrated set of project requirements, cost, schedule, technical content, and an agreed-to JCL that forms the basis for NASA’s commitment with the external entities of OMB and Congress. Only one official baseline exists for a NASA program or project and it is the commitment Baseline.

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**Complex Item.** A product that has quality characteristics not wholly visible in the end item, for which contract conformance cannot be determined through inspection, measurement, and/or test of the end item, and for which conformance can only be established progressively through the item's life by precise measurements, tests, and controls applied. Examples of complex items include assemblies, machinery, equipment, subsystems, systems, and platforms.

**Compliance Verification.** Compliance verification includes: 1) verifying that appropriate technical and process requirements are in place (requirements flow-down verification), 2) verifying that documented SMA requirements are in place and capable, and 3) observing work activities and products to verify process implementation and compliance with process and technical requirements (e.g., on-site in-process audits and reviews for verification of work discipline.)

**Computer Security.** The protection afforded to an automated information system in order to attain the applicable objectives of preserving the integrity, availability, and confidentiality of information system resources (including hardware, software, firmware, information/data, and telecommunications).

**Concurrence.** A documented agreement by a management official that a proposed course of action is acceptable.

**Configuration Control Board (CCB).** Is constituted to control and authorize baselines, changes, deviations and waivers to configuration controlled documents and other specific program-level activities.

**Configuration Management.** A management discipline applied over the product's life cycle to provide visibility into and to control changes to performance, functional, and physical characteristics.

**Conjunction Assessment.** An analysis done to predict the closest point of approach of two space objects based on their orbital parameters.

**Continuous Risk Management (CRM).** A systematic and iterative process that efficiently identifies, analyzes, plans, tracks, controls, communicates, and documents risks associated with implementation of designs, plans, and processes.

**Contract Data Requirements List.** A listing of the technical information and reports required for a contract including submittal and approval criteria and instruction.

**Contract.** A mutually binding legal relationship obligating the seller to furnish the supplies or services (including construction) and the buyer to pay for them. It includes all types of commitments that obligate the Government to an expenditure of appropriated funds and that, except as otherwise authorized, are in writing. In addition to bilateral instruments, contracts include (but are not limited to) awards and notices of awards; job orders or task letters issued under basic ordering agreements; letter contracts; orders, such as purchase orders, under which



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the contract becomes effective by written acceptance or performance; and bilateral contract modifications. Contracts do not include grants and cooperative agreements.

**Convening Authority.** The management official(s) responsible for convening a program/project review, establishing the terms of Reference, including review objectives and success criteria, appointing the SRB chair, concurring on SRB membership, and receiving documented results of the review.

**Council on Environmental Quality.** The President's Council on Environmental Quality (CEQ) was established by the enactment of NEPA. The CEQ was charged with developing regulations to be followed by all Federal agencies in developing and implementing their own specific NEPA implementation policies and procedures.

**Countermeasures.** Actions, devices, procedures, techniques, or other measures that reduce the vulnerability of an information system. Synonymous with security controls and safeguards.

**Critical Path.** A sequential path of tasks in a network schedule that represents the longest overall duration from "time now" through project completion. Any slippage of the tasks in the critical path will increase the project duration.

**Critical Single Failure Point.** A single item or element, essential to the safe functioning of a system or subsystem, whose failure in a life or mission-essential application would cause serious delays or be hazardous to personnel.

**Decision Authority (DA).** The individual responsible for evaluating independent assessments and program and project Governing Body recommendations, assessing program and project deliverables, and making the decision at a KDP that authorizes a program or project to transition to the next life cycle phase.

**Decommissioning Review.** Confirms the decision to terminate or decommission the system and assess the readiness of the system for the safe decommissioning and disposal of system assets.

**Derived Requirement.** Arise from constraints, consideration of issues implied but not explicitly stated in the high-level direction provided by NASA HQ and Center institutional requirements, factors introduced by the selected architecture, and the design. These requirements are finalized through requirements analysis as part of the overall systems engineering process and become part of the program/project requirements baseline. They are established by and are the responsibility of the Programmatic Authority.

**Designated Governing Authority.** The management entity above the program, project, or activity level with technical oversight responsibility.

**Deviation.** . A documented authorization intentionally releasing a program or project from meeting a requirement before the requirement is put under configuration control at the level the requirement will be implemented. .

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**Dissenting Opinion.** A Dissenting Opinion is a disagreement with a decision or action that is based on a sound rationale (not on unyielding opposition) that an individual judges is of sufficient importance that it warrants a specific review and discussion by higher level management and the individual specifically requests

**Dominant Root Cause.** Along a chain of events leading to a mishap, the first causal action or failure to act that could have been controlled systematically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

**Earned Value Management (EVM).** A tool for measuring and assessing project performance through the integration of technical scope with schedule and cost objectives during the execution of the project. EVM provides quantification of technical progress, enabling management to gain insight into project status and project completion costs and schedules. Two essential characteristics of successful EVM are EVM system data integrity and carefully targeted monthly EVM data analyses (i.e., risky WBS elements).

**Earned Value.** The sum of the budgeted cost for tasks and products that have actually been produced (completed or in progress) at a given time in the schedule.

**End-of-Mission.** The time of completion of all mission activities, experimental operations, and stand-by-status, that immediately precedes passivation and disposal of the spacecraft or launch vehicle stage.

**Engineering Requirements.** Requirements defined to achieve programmatic requirements and relating to the application of engineering principles, applied science, or industrial techniques.

**Environmental Evaluation.** An environmental evaluation is the analysis of the environmental effects of proposed actions, including alternative proposals. The analyses are carried out from the very earliest of planning studies for the action in question and are the materials from which the more formal environmental assessments, environmental impact statements, and public record of decisions are made.

**Environmental Impact.** The direct, indirect, or cumulative beneficial or adverse effect of an action on the environment.

**Environmental Management Division—HQ.** The Headquarters Environmental Management Division (HQ/EMD) assists the Assistant Administrator for Institutional and corporate Management in implementing assigned environmental management duties and responsibilities for NEPA functions. HQ/EMD is available for consultation and non-legal advice to other NASA entities for implementing assigned environmental responsibilities under NEPA.

**Environmental Management.** The activity of ensuring that program and project actions and decisions that potentially impact or damage the environment are assessed/evaluated during the formulation/planning phase and reevaluated throughout implementation. This activity must be performed according to all NASA policy and Federal, state and local environmental laws and regulations.

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**Estimate at Completion (EAC).** The sum of actual direct costs, plus indirect costs allocable to the project/contract to date, plus the estimate of costs (direct and indirect) for authorized work remaining and reserves.

**Evaluation.** The continual, independent (i.e., outside the advocacy chain of the program/project) evaluation of the performance of a program or project and incorporation of the evaluation findings to ensure adequacy of planning and execution according to plan.

**Expedition.** A series of crewed or uncrewed aircraft flights, generally focused on a specific geographic area, designed to gather scientific measurements of Earth characteristics over a period of time.

**Experiment.** Generally refers to the instrument making the scientific measurements of Earth characteristics; can also refer to overall proposed scientific investigation approach.

**Export Administration Regulations (EAR).** US export control regulations administered by the US Department of commerce that require limited availability for technical Data pertaining to commodities, technology and software listed on the commerce Control List. NASA STI reports subject to restriction under this regulation often are referred to as EAR documents.

**Factor of Safety.** Ratio of the design condition to the maximum operating conditions specified during design.

**Fail-Safe.** Ability to sustain a failure and retain the capability to safely terminate or control the operation.

**Failure Mode.** Particular way in which a failure can occur, independent of the reason for failure.

**Failure Modes and Effects Analysis (FMEA).** A bottoms-up systematic, inductive, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of the modes of failure. It is usually performed to identify critical single failure points in hardware. In relation to formal hazard analysis, FMEA is a subsidiary analysis.

**Failure Review Board (FRB).** A group consisting of representatives from appropriate organizations with the level of responsibility and authority to assure that causes are identified and corrective actions are implemented. The board reviews failure trends, facilitates and manages the failure analysis and participates in developing and implementing the resulting corrective actions. The board's authority is designed to require investigations, analyses, and corrective actions by other organizations. The board should be headed by the reliability manager.

**Failure Tolerance.** Built-in capability of a system to perform as intended in the presence of specified hardware or software failures.

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**Failure.** Inability of a system, subsystem, component, or part to perform its required function within specified limits.

**Fault Tree Analysis (FTA).** An analysis that begins with the definition or identification of an undesired event (failure). The fault tree is a symbolic logic diagram showing the cause-effect relationship between a top undesired event (failure) and one or more contributing causes. It is a type of logic tree that is developed by deductive logic from a top undesired event to all sub-events that must occur to cause it.

**Fault Tree.** A schematic representation resembling an inverted tree that depicts possible sequential events (failures) that may proceed from discrete credible failures to a single undesired final event (failure). A fault tree is created retrogressively from the final event by deductive logic.

**Final (Document Context).** Implies the expectation of a finished product. All approvals required by Center policies and procedures have been obtained.

**Final Acceptance.** The act of an authorized representative of the government by which the government, for itself or as an agent of another, assumes ownership of existing identified supplies tendered or approves specific services rendered as partial or complete performance of the contract.

**Finding.** A conclusion, positive or negative, based on facts established during the investigation by the investigating authority (i.e., cause, contributing factor, and observation).

**Firewall.** A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both. Firewalls are frequently used to prevent unauthorized internet users from accessing private networks connected to the Internet, especially intranets. All messages entering or leaving the intranet pass through the firewall, which examines each message and blocks those that do not meet the specified security criteria.

**Flight Hardware.** Any hardware that is flown on or is a part of an aircraft, experimental flight vehicle, satellite, lighter than air vehicles, unoccupied aerial vehicle, or space transportation system.

**Flight.** A single crewed or uncrewed activity from takeoff to landing.

**Foreign National.** (For the purpose of general security protection, considerations of national security and access accountability.) Any person who is not a citizen of the US. Includes lawful permanent resident (i.e., holders of green cards) or persons admitted with refugee status to the US.

**Formulation Phase.** The first part of the NASA management life cycle where system requirements are baselined, feasible concepts are determined, a system baseline is baselined for the selected concept (s), and preparation is made for progressing to the implementation phase.

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**Functional Redundancy.** A situation where a dissimilar device provides safety backup rather than relying on multiple identical devices.

**Gantt Chart.** Bar chart depicting start and finish dates of activities and products in the WBS.

**General Correspondence.** A file consisting of correspondence by organizations as a result of their routine operations. Records consist of arrangement of correspondence, memoranda, and messages on a number of different subjects as distinguished from a case file that contains correspondence about specific transactions or projects.

**GIDEP ALERT.** GIDEP document for reporting a problem with parts, components, materials, specifications, software, facilities, manufacturing processes, or test equipment that can cause a functional failure.

**GIDEP.** This acronym stands for “Government-Industry Data Exchange Program”. GIDEP is a cooperative information-sharing program between the US and Canadian governments and industry participants. The goal of GIDEP is to ensure that only reliable and conforming parts are in use on all Government programs and operations. GIDEP members share technical information essential to the research, design, development, production, and operational phases of the life cycle of systems, facilities, and equipment.

**Government Mandatory Inspection Points.** Inspection points required by Federal regulations to ensure 100 percent compliance with safety/mission-critical attributes when noncompliance can result in loss of life or loss of mission.

**Ground Support Equipment.** Ground-based equipment used to store, transport, handle, test check out, service and control aircraft, launch vehicles, spacecraft, or payloads.

**Hazard Analysis.** Identification and evaluation of existing and potential hazards and the recommended mitigation for the hazard sources found.

**High Risk Item.** An item which involves technological manufacturing or other state-of-the-art advances or considerations, and program/project management designates as requiring special attention. It is critical from the standpoint of achieving program objectives, reliability, maintainability safety, quality assurance, or other such factors.

**Hydros.** An ESSP investigation that did not complete formulation, whose mission was to conduct global observations of daily surface freeze/thaw state and soil moisture conditions.

**Implementation Phase.** The part of the NASA management life cycle where the detailed design of system products is completed and the products to be deployed are fabricated, assembled, integrated, and tested and the products are deployed to their customers or users for their assigned use or mission.

**Independent Assessment.** The general term referring to an evaluation of a program or project conducted by experts outside the advocacy chain. Specifically, a review or evaluation that

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results in an assessment of the program's or project's readiness (technical, schedule, cost, risk) to proceed to the next phase in the life cycle that is reported to a program or project governing body and DA..

**Independent Cost Analysis (ICA).** An independent analysis of program/project resources (including budget) and financial management associated with the program/project content over the program's budget horizon, conducted by an impartial body independent from the management or advocacy chain of the program/project. ICA includes, but is not limited to, the assessment of cost estimates, budgets, and schedules in relation to a program/project and a program's constituent projects' technical content, performance and risk. ICAs may include Independent Cost Estimates (ICE) assessment of resource management, distribution, and planning, and verification of cost-estimating methodologies. (ICAs are not life cycle cost estimates but are assessments of the budget and management practices to accomplish the work scope through the budget horizon; as such, ICAs can be performed for programs/projects when a life cycle ICE is not warranted.)

**Independent Cost Estimate (ICE).** An independent program/project cost estimate prepared by an office or other entity that is not under the supervision, direction, advocacy, or control of the program/project (or its chain of command) that is responsible for carrying out the development or acquisition of the program/project. An ICE is bounded by the program/project scope (total life cycle through all phases), schedule, technical content, risk, ground rules, and assumptions and is conducted with objectivity and the preservation of integrity of the cost estimate. ICEs are generally developed using parametric approaches that are tailored to reflect the design, development state, difficulty, and expertise of team members.

**Information System.** The term "information system" means a discrete set of information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information. Information systems are also referred to as IT systems.

**Information Technology (IT).** Any equipment, or interconnected system(s) of subsystem(s) of equipment, that is used in the automatic acquisition, storage, analysis, evaluation, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the Agency

**Insight.** Surveillance mode requiring the monitoring of customer-identified metrics and contracted milestones. Insight is a continuum that can range from low intensity, such as reviewing quarterly reports, to high intensity, such as performing surveys and reviews.

**Integrated Baseline.** The project's technical performance and content, technology application, schedule milestones and budget. The integrated baseline includes the WBS, WBS dictionary, integrated master schedule, preliminary life cycle cost estimate, and workforce estimate, consistent with the program requirements on the project.

**Integrated Master Schedule (IMS).** An integrated set of schedule data that reflects the total project scope of work as discrete and measureable tasks/milestones that are time phased through the use of task durations, interdependencies, and date constraints and is traceable to the WBS.

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The highest level schedule is the Master Schedule supported by Intermediate Level Schedules and by lowest level detail schedules.

**International Partners.** Foreign Nationals or US citizen representative of foreign governments, who are involved in a particular international program or project under an International Space Act Agreement (ISAA).

**International Traffic in Arms Regulations (ITAR).** US Export Control Regulations that require limited availability for technical data that pertain to commodities, technology, and software listed on the US Munitions List. NASA STI reports subject to restriction under this regulation are often referred to as ITAR documents.

**Investigation.** Generally refers to a proposed scientific endeavor involving measurements of Earth characteristics over a period of time and geographic location; can also refer to determination of root cause of unexpected event.

**Joint Cost and Schedule Confidence Level (JCL).** (1) The probability that cost will be equal to or less than the targeted cost and schedule will be equal to or less than the targeted schedule date. (2) A process and product that helps inform management of the likelihood of a project's programmatic success. (3) A process that combines a project's cost, schedule, and risk into a complete picture. JCL is not a specific methodology (e.g., resource loaded schedule) or a product from a specific tool (e.g., @RISK).

**Key Decision Point (KDP).** The event at a point in time in the program or project life cycle, usually at the end of a program or project life cycle phase, when the program or project DA makes the decision (or not) to authorize the program or project to transition to its next life cycle phase. Program KDPs are designated with roman numerals, e.g., KDP II, and project KDPs are designated with letters, e.g., KDP B.

**Key Performance Parameters (KPP).** Quantitative metrics selected by the Project Manager in order to measure the effectiveness of the project in achieving their goals and related mission success criteria.

**Knowledge Management.** Getting the right information to the right people at the right time without delay while helping people create knowledge and share and act upon information in ways that will measurably improve the performance of NASA and its partners.

**Lawful Permanent Resident (LPR).** (Replaces the term "Permanent Resident Alien") A non US citizen legally permitted to reside and work within the US and issued the Resident Alien Identification (green card). Afforded all the rights and privileges of a US citizen with the exception of voting, holding public office, employment in the Federal sector (except for specific needs or under temporary appointments), and access to classified national security information.

**Legacy.** These are usually software products (architecture, code, requirements) written specifically for one project and then, without prior planning during its initial development, found to be useful on other projects.

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**Lesson Learned.** The significant knowledge or understanding gained through past or current programs and projects that is documented and collected to benefit current and future programs and projects.

**Liens.** Requirements or tasks not satisfied that have to be resolved within a certain assigned time to allow passage through a control gate to proceed.

**Life cycle Cost (LCC).** The LCC of a project or system can be defined as the total cost of ownership over the project's or system's life cycle from Formulation through Implementation. The total of direct, indirect, recurring, nonrecurring, and other related expenses incurred, or estimated to be incurred, in the design, development, verification, production, deployment, operation, maintenance, support and disposal of a project.

**Logistics.** The management, engineering activities, and analysis associated with design requirements definition, material procurement and distribution, maintenance, supply replacement, transportation, and disposal that are identified by space flight and ground systems supportability objectives.

**Management Baseline.** The integrated set of requirements, cost, schedule, technical content, and associated JCL that forms the foundation for program/project execution and reporting done as part of NASA's performance assessment and governance process.

**Management Process Requirements.** Requirements that focus on how NASA does business that are independent of the particular program or project. There are four types: engineering, program/project management, safety and mission assurance, and Mission Support Office functional requirements.

**Margin of Safety.** Deviation of the actual (operating) factor of safety from the specified factor of safety. Can be expressed as a magnitude or percentage relative to the specified factor of safety.

**Margin.** The allowances carried in budget, projected schedules, and technical performance parameters (e.g. weight, power, or memory) to account for uncertainties and risks. Margin allocations are baselined in the formulation process based on assessments of risk, and are typically consumed as the program/project proceeds through the life cycle.

**Metric.** A measurement taken over a period of time that communicates vital information about the status or performance of a system, process, or activity. A metric should drive appropriate action.

**Milestone.** An event of particular significance. Finitely defined events that constitute the start or completion of a task or occurrence of an objective criterion for accomplishment. Milestones should be discretely identifiable, the passage of time alone is not sufficient to constitute a milestone. However, milestones should be associated with schedule data to document when the milestone is to occur.



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**Mission Assurance.** Providing increased confidence that applicable requirements, processes, and standards for the mission are being fulfilled.

**Mission Critical.** Item or function that must retain its operational capability to assure no mission failure (i.e., for mission success).

**Mission Directorate Program Management Council.** The senior management group, chaired by a MDAA or designee, responsible for reviewing project formulation performance, recommending approval, and overseeing implementation of Category 2 and 3 projects according to agency commitments, priorities and policies.

**Mission Failure.** A mishap of whatever intrinsic severity that prevents the achievement of the mission's minimum success criteria or minimum mission objectives as described in the mission operations report or equivalent document.

**Mission Manager.** Member of the Program Office staff responsible for ensuring Program Office support for each ESSP constituent Project. Specifically, this includes establishing and maintaining effective working relations with the Projects, leading the analysis of Project performance and leading the analysis of mission implementation processes.

**Mission Operations.** All activities executed by the spacecraft; includes design mission, prime mission, secondary mission, extended mission, and disposal.

**Mission.** A major activity required to accomplish an Agency goal or to effectively pursue a scientific, technological, or engineering opportunity directly related to an Agency goal. Mission needs are independent of any particular system or technological solution. Can also refer to period in project life cycle after beginning flight operations.

**NASA Policy Directive (NPD).** HQ level document establishing NASA policy.

**NASA Procedural Requirement (NPR).** HQ level document that defines process requirements.

**Network Administrator.** A person who manages a local area network (LAN) within an organization. Responsibilities include network security, installing new applications, distributing software upgrades, monitoring daily activity, enforcing licensing agreements, developing a storage management program and providing for routine backups.

**New Obligation Authority (NOA).** Approval to obligate resources to the level specified.

**Noncompliance.** A failure to comply with Federal, State, local, Agency and/or Center requirements. A noncompliance could lead to the loss of life or injury to NASDA personnel or the public, loss of or damage to high-value equipment, or reduction of the likelihood of mission success.

**Nonconformance.** The state or situation of not fulfilling a requirement.

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**Nonrecord Material.** Material such as extra copies of documents and correspondence that are kept only for convenience or reference, stocks of publications and professional documents, personal records, reference items and library or museum material intended solely for reference or exhibition.

**Observation.** A factor, event, or circumstance identified during the investigation that did not contribute to the mishap or close call, but, if left uncorrected, has the potential to cause a mishap or increase the severity of a mishap; or a factor, event, or circumstance that is positive and should be noted.

**Office of Record.** An office designated as the official custodian of records for a specified program, activity, or transaction of an organization. Under functional or decentralized filing plans, the Office of Record is usually the office which created the record or initiated the action on an incoming record, unless otherwise designated. Under centralized filing, the central file(s) are designated or become the Office of Record.

**Operability.** As applied to a system, subsystem, component, or device is the capability of performing its specified function (s) including the capability of performing its related support function (s).

**Orbital Debris.** Any object placed in space by humans that remains in orbit and no longer serves any useful function. Objects range from spacecraft to spent launch vehicle stages to components and also include materials, trash, refuse, fragments, and other objects which are overtly or inadvertently cast off or generated.

**Other Interested Parties (Stakeholders).** A subset of “stakeholders” other interested parties are groups or individuals who are not customers of a planned technical effort but may be affected by the resulting product, the manner in which the product is realized or used, or have a responsibility for providing life cycle support services.

**Outcome.** Outcomes are multiyear performance measures of NASA’s progress toward achieving longer-term strategic objectives and strategic goals. Performance on an outcome is determined by weighing the performance of associated annual performance goals against management’s timeline for achieving the outcome.

**Oversight/Insight.** The transition in NASA from a strict compliance-oriented style of management to one which empowers line managers, supervisors, and employees to develop better solutions and processes. To monitor actively the implementation of assigned actions, policy and procedures. HQ officials with an oversight role have the responsibility to establish and track performance parameters to ensure assignees are properly implementing their actions, policies, and procedures.

**Passivation.** The process of removing all forms of stored energy from spacecraft, launch vehicle stages, and propulsion units. Passivation includes, but is not limited to, the depletion of all residual propellants, pressurants, electrical storage devices, and forms of kinetic energy to a level where the remaining internal stored energy is insufficient to cause breakup/disassembly. Some

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sealed batteries and heat pipes need not be depressurized if their potential for explosion is extremely low.

**Peer-Review.** Independent evaluation by internal or external subject matter experts who do not have a vested interest in the work product under review. Peer reviews can be planned focused reviews, conducted on selected work products by the producer's peers to identify defects and issues prior to that work product moving into a milestone review or approval cycle.

**Performance Budget.** A budget that clearly links performance goals with costs for achieving a target level of performance. In general, a performance budget links strategic goals with related long term and annual performance goals (outcomes) with the costs of specific activities to influence these outcomes about which budget decisions are made.

**Performance Goal.** A target level of performance at a specified time or period expressed as a tangible, measurable outcome, against which actual achievement can be compared, including a goal expressed as a quantitative standard value or rate. A performance goal comprises a performance measure with targets and time frames. The distinction between "long term" and "annual" refers to the relative timeframes for achievement of the goals.

**Permanent Records.** In US government usage, records appraised by NARA as having enduring value because they document the organization and functions of the agency that created or received them, and/or, because they contain significant information on persons, things, problems, programs, projects and conditions with which the agency dealt. These records are valuable or unique in that they document the history of the Agency and generally record prime missions, functions, responsibilities and significant experiences or accomplishments of the agency.

**Post mission Disposal.** The orbit/location where a spacecraft/launch vehicle is left after passivation at EOM.

**Precursor.** An occurrence of one or more events that have significant failure or risk implications.

**Preliminary (Document Context).** Implies that the product has received initial review in accordance with Center best practices. The content is considered correct, though some TBDs may remain. All approvals required by Center policies and procedures have been obtained. Major changes are expected.

**Principal Investigator (PI).** A person who conceives an investigation and is responsible for carrying it out and reporting its results. In some cases, PIs from industry and academia act as project managers for smaller development efforts with NASA personnel providing oversight.

**Probabilistic Risk Assessment (PRA).** A systematic, logical, and comprehensive tool to assess risk (likelihood of unwanted consequences) for the purpose of 1) characterizing and improving system performance and mission success; 2) increasing safety in design, operation and upgrade, and 3) saving money in design, manufacturing or assembly, and operation.

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**Process.** A set of activities used to convert inputs into desired outputs to generate expected outcomes and satisfy a purpose.

**Procurement Strategy Meeting (PSM).** A forum where management reviews and approves the approach for the Agency's major and other selected procurements. Chaired by the Assistant Administrator of Procurement (or designee), the PSM addresses and documents information, activities, and decisions from the ASP and ASM strategic procurement meetings to insure the alignment of individual procurement action with NASA's portfolio and mission. Detailed PSM requirements and processes, prescribed by the FAR and NFS and formulated by the Office of Procurement, ensure the alignment of portfolio, mission acquisition and subsequent procurement decisions.

**Program (Project) Team.** All participants in program (project) formulation and implementation. This includes all direct reports and others that support meeting program (project) responsibilities.

**Program Commitment Agreement.** The contract between the Associate Administrator and the responsible MDAA that authorizes transition from formulation to implementation of a program.

**Program Management Council (PMC).** One of the hierarchy of forums composed of senior management that assesses program or project planning and implementation, and provides oversight and direction as appropriate. These are established at the Agency or Mission directorate levels.

**Program Plan.** The document that establishes the Programs' baseline for implementation, signed by the MDAA and Center Director(s).

**Program.** A strategic investment by a Mission Directorate or Mission Support Office that has a defined architecture and/or technical approach, requirements, funding level, and a management structure that initiates and directs one or more projects. A program defines a strategic direction that the Agency has identified as critical.

**Program/Project Management Requirements.** Requirements that focus on how NASA and Centers perform program and project management activities.

**Program-Level Requirements Appendix (PLRA).** The document that establishes the baseline for project implementation, including the Level 1 requirements as well as the agreements among the Program Executive, Program Scientist, cognizant SMD Division Director, managing Center Director, implementing Center Director, and Program Manager. This document is an appendix to the Program Plan under whose management authority it reports at the NASA Center.

**Programmatic Authority.** Programmatic Authority includes of the Mission Directorates and their respective program and project managers. Individuals in these organizations are the official voices for their respective areas. Programmatic Authority sets, oversees, and ensures conformance to applicable programmatic requirements.

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**Programmatic Requirement.** Requirements set by the mission directorate, program, project, and PI, if applicable. These include strategic scientific and exploration requirements, system performance requirements, and schedule, cost, and similar nontechnical constraints.

**Project Plan.** A detailed plan which, when formally approved, sets forth the agreement between a program manager and project managers, and defines the guidelines and constraints under which the project will be executed.

**Project.** A specific investment identified in a *Program Plan* having defined requirements, a life cycle cost, a beginning, and an end. A project yields new or revised products that directly address NASA's strategic needs. Can also refer to time in project life cycle after proposal selection and before beginning flight operations.

**Quality Assurance.** An independent assessment needed to have confidence that the system actually produced and delivered is in accordance with its functional, performance and design requirements.

**Recommendation.** An action developed by the investigating authority to correct the cause or a deficiency identified during the investigation.

**Redundancy.** Use of more than one independent means to accomplish a given function.

**Reliability Analysis.** An evaluation of reliability of a system or portion thereof. Such analysis usually employs mathematical modeling, directly applicable results of tests on system hardware, estimated reliability figures, and non-statistical engineering estimates to ensure that all known potential sources of unreliability have been evaluated.

**Reliability.** The measure of the degree to which a system ensures mission success by functioning properly over its intended life. It has a low and acceptable probability of failure, achieved through simplicity, proper design, and proper application of reliable parts and materials. In addition to long life, a reliable system is robust and fault tolerant.

**Reserves.** Resources (funding, schedule, performance, manpower, and services) held back by a manager, which can be allocated for expansion, unforeseen events, or other adjustments when they occur.

**Resource Loading.** The process of recording resource requirements for a schedule task/activity or a group of tasks/activities.

**Risk Analysis.** An evaluation of all identified risks to estimate the likelihood of occurrence, consequence of impact, timeframe of expected occurrence or when mitigation actions

**Risk Assessment.** An evaluation of a risk item that determines (1) what can go wrong, (2) how likely is it to occur, (3) what the consequences are, and (4) what are the uncertainties associated with the likelihood and consequences.

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**Risk Classification.** 1) The process of grouping risks into high, moderate, and low categories based on the likelihood and consequence adjective ratings. High, moderate, and low risks are represented by colors red, yellow, and green, respectively. 2) The process of grouping risks based on shared characteristics or relationships among risks. Classification helps to identify duplicate risks and supports simplifying the list of risks. Affinity grouping is a form of risk classification.

**Risk Control.** An activity that utilizes the status and tracking information to make a decision about a risk mitigation effort. A risk may be accepted, watched, researched, mitigated, or closed. A mitigation action may be re-planned or a contingency plan may be invoked. Decisions on the appropriate resources needed are also determined during this risk control activity.

**Risk Exposure.** The product of Likelihood (Probability) and Consequence (Impact) components of a risk used to prioritize risk to a program. (Risk Exposure=Probability x Impact)

**Risk Identification.** A continuous effort to capture, acknowledge and document risks as they are identified.

**Risk Management.** Risk management includes risk-informed decision making and continuous risk management in an integrated framework. This is done in order to foster proactive risk management, to better inform decision making through better use of risk information, and then to more effectively manage implementation risks by focusing the CRM process on the baseline performance requirements emerging from the RIDM process. (See NPR 8000.4).

**Risk Mitigation Plan.** A formal plan developed to eliminate or reduce a risk's exposure by either reducing its likelihood of occurrence and/or its impact. A Risk management Database (RMD) will be used to enter the risk mitigation plan. The plan should also identify a fallback plan to identify specific action to be taken if the Risk Mitigation Plan is not effective.

**Risk Mitigation.** The elimination or reduction of an identified risk by reducing the consequences, by reducing the likelihood, or by shifting the timeframe.

**Risk Owner.** An individual assigned by the program through the RMB to implement action/mitigation plans and activities needed to close or accept a specific risk with the authority and resources to action on a preapproved plan. The individual designated as the lead for overseeing the implementation of the agreed disposition of that risk.

**Risk Review Board.** Formally established groups of people assigned specifically to review risk information. Their output is twofold: (1) to improve the management of risk in the area being reviewed and (2) to serve as an input to decision-making bodies in need of risk information.

**Risk Tracking.** An activity to capture, compile, and report risk attributes and metrics that determine whether or not risks are being mitigated effectively and whether risk mitigation plans are being implemented correctly.

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**Risk.** The combination of the probability that a program or project will experience an undesired event and the consequences, impact, or severity of the undesired event, was it to occur. The undesired event may come from technical or programmatic sources (e.g., a cost overrun, schedule slippage, safety mishap, health problem, malicious activities, environmental impact, failure to achieve a needed scientific or technological objective, or success criterion). Both the probability and consequences may have associated uncertainties.

**Risk-Based Acquisition Management.** The integration of risk management into the NASA Acquisition Process

**Risk-Informed Decision Analysis Process.** A five-step process focusing first on objectives and next on developing decision alternatives with those objectives clearly in mind and/or using decision alternatives that have been developed under other systems engineering processes. The later steps of the process interrelate heavily with the Technical risk Management Process.

**Risk-Informed Decision Making (RIDM).** A risk-informed decision making process uses a diverse set of performance measures (some of which are risk-based risk metrics)) along with other considerations without a deliberative process to inform decision making.

**Root Cause Analysis.** A structured evaluation method that identifies the root causes for an undesired outcome and the actions adequate to prevent recurrence. Root cause analysis should continue until organizational factors have been identified or until data are exhausted.

**Safety and Mission Assurance Requirements.** Requirements defined by the SMA organization related to safety and mission assurance.

**Safety Critical.** Term describing any condition, event, operation, process, equipment, or system that could cause or lead to severe injury, major damage, or mission failure if performed or built improperly, or allowed to remain uncorrected.

**Safety.** Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.

**Schedule Logic Network.** A schedule format in which tasks/activities and milestones are represented along with their relevant interdependencies, constraints, and durations. It expresses the logic as to how the work scope will be accomplished. Logic network schedules are the basis for critical path analysis, which is a method for identification and assessment of schedule priorities and impacts.

**Schedule Risk Assessment (SRA).** The process of performing a probabilistic risk assessment on a project schedule. This type of schedule assessment is based on using Monte Carlo simulations that incorporate minimum, maximum, and most likely estimates for task durations.

**Scientific and Technical Information (STI).** NASA STI is defined as the results (facts, analyses, and conclusions) of the Agency's basic and applied scientific, technical, and related engineering research and development. STI also includes management, industrial and economic

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information relevant to this research. Examples include, but are not limited to, technical papers and reports, journal articles, meeting, workshop and conference papers and presentations, conference proceedings, preliminary or non-published STI, including any of these examples that will be posted to a public website.

**Scientific and Technical Information-Formal.** Scientific and technical information intended for publication in the NASA STI Report Series (e.g., Technical Memorandum, conference Publication) or as a professional journal article or presentation for which the NASA STI Program maintains responsibility for dissemination and preservation.

**Scientific and Technical Information-Informal.** Scientific and technical information not intended for initial publication in the NASA STI Report Series or as a professional journal article or presentation for which the NASA STI Program maintains responsibility for dissemination and preservation.

**Security.** Protection of people, property, and information assets owned by NASA, which covers physical assets, personnel, IT, communications, and operations.

**Sensitive But Unclassified (SBU).** Information, data, or systems that require protection due to the risk and magnitude of the harm or loss that could result from unauthorized disclosure, alteration, loss or destruction but has not been designated as classified for national security purposes.

**Single Failure Point.** An independent element of a system (hardware, software, or human) the failure of which would result in loss of objectives, hardware, or crew.

**Solicitation.** The vehicle by which information is solicited from contractors to let a contract for products or services.

**Stakeholder Expectations.** A statement of needs, desires, capabilities and wants, that are not expressed as requirements (not expressed as a “shall” statement) is to be referred to as an “expectation”. Once the set of expectations from applicable “stakeholders” is collected, analyzed, and converted into a “shall” statement, the expectation becomes a requirement. Expectations can be stated in either qualitative (nonmeasureable) or quantitative (measurable) items. Requirements are always stated in quantitative terms. Expectations can be stated in terms of functions, behaviors, or constraints with respect to the product being engineered or the process used to engineer the product.

**Stakeholder.** An individual or organization that is materially affected by the outcome of a decision or deliverable but is outside the organization doing the work or making the decision. A group or individual who is affected by or is in some way accountable for the outcome of an undertaking. The term “relevant stakeholder” is a subset of the term “stakeholder” and describes the people identified to contribute to a specific task. There are two main classes of stakeholders (see “Customers” and “Other Interested Parties”



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**Standing Review Board (SRB).** The entity responsible for conducting independent reviews (life cycle and special) of the program/project. The reviews are conducted in accordance with approved ToR and the life cycle requirements per NPR 7120.5 and NPR 7123.1. The SRB is advisory and is chartered to objectively assess the material presented by the program/project at a specific review.

**Statement of Work (SOW).** A document that contains a narrative description of the work scope requirements for a project or contract.

**Subject Matter Expert (SME).** An individual who possesses in-depth expert knowledge of a program, process, technology, or information sufficient to establish classification caveats or determining the need or appropriateness of an existing national security classification.

**Success Criteria.** That portion of the top-level requirements that define what must be achieved to successfully satisfy NASA Strategic Plan objectives addressed by the program/project. Specific accomplishments that must be successfully demonstrated to meet the objectives of a technical review so that a technical effort can progress further in the life cycle. Standards against which the program/project will be deemed a success. Success criteria are documented in the corresponding technical review plan. Success criteria may be both qualitative and quantitative, and may cover mission cost, schedule and performance results, as well as actual mission outcomes.

**System Administrator.** A person who manages a multi-user computer system. Responsibilities are similar to that of a network administrator. A system administrator would perform systems programmer activities with regard to operating system and other network control programs.

**System.** The combination of elements that function together to produce the capability required to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose.

**Systems Engineering.** A disciplined approach for the definition, implementation, integration, and operation of a system (product or service). The emphasis is on achieving stakeholder functional, physical and operational performance requirements in the intended use environments over its planned life within cost and schedule constraints. Systems engineering includes the engineering processes and technical management processes that consider the interface relationships across all elements of the system, other systems, or as a part of a larger system.

**Tailoring.** The process used to adjust or seek relief from a prescribed requirement to accommodate the needs of a specific task or activity (e.g., program or project). The tailoring process results in the generation of deviations and waivers depending on the timing of the request.

**Technical Authority (TA).** Technical Authorities are part of NASA's system of checks and balances and provide independent oversight of programs and projects in support of safety and mission success through the selection of individuals at selected levels of authority. These individuals are the Technical authorities. Technical authority delegations are formal and

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traceable to the Administrator. Individuals with Technical authority are funded independently of a program or project.

**Technical Performance Measures.** The set of critical or key performance parameters that are monitored by comparing the current actual achievement of the parameters with that anticipated at the current time and on future dates. Used to confirm progress and identify deficiencies that might jeopardize meeting a system requirement. Assessed parameter values that fall outside an expected range around anticipated values indicate a need for evaluation and corrective action. Technical performance measures are typically selected from the defined set of measures of performance.

**Technology Readiness Level (TRL).** Provides a scale against which to measure the maturity of a technology. TRLs range from 1 (Basic Technology Research) to 9 (Systems Test, Launch, and Operations). Typically, a TRL of 6 (i.e. technology demonstrated in a relevant environment) is required for a technology to be integrated into a Systems Engineering process.

**Termination Review.** A review initiated by the DA for the purpose of securing a recommendation as to whether to continue or terminate a program or project. Failing to stay within the parameters or levels specified in controlling documents will result in consideration of a termination review.

**Terms of Reference (ToR).** A document specifying the nature, scope, schedule, and ground rules for an independent review or independent assessment.

**Threshold (or Minimum) Science Requirements.** The minimum performance requirements necessary to achieve the minimum science acceptable for the investment. In some solicitations used for competed missions, threshold science requirements may be called the “science floor” for the mission. This is the KPP threshold.

**Traceability.** A discernible association among two or more logical entities such as requirements, system elements, verifications, or tasks.

**Validate Risk.** The process of examining an identified potential risk to verify that it is a threat to the project and has been written in such a way as to allow further analysis and that mitigation actions are within the scope of the program, project, or task in question.

**Validated Requirements.** A set of requirements that are well formed (clear and unambiguous), complete (agree with customer and stakeholder needs and expectations), consistent (conflict free), and individually verifiable and traceable to a higher level requirement or goal.

**Validation.** Proof that the product accomplishes the intended purpose based on stakeholder expectations. May be determined by a combination of test, analysis, demonstration, and inspection. (1) An evaluation technique to support or corroborate safety requirements to ensure necessary functions are complete and traceable; or (2) the process of evaluating software at the end of the software development process to ensure compliance with software requirements.

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**Variance.** In program control terminology, a difference between actual performance and planned cost or schedule status.

**Verification.** Proof of compliance with design solution specifications and descriptive documents. May be determined by a combination of test, analysis, demonstration, and inspection. (1) The process of determining whether the products of a given phase of the software development cycle fulfill the requirements established during the previous phase; or (2) formal proof of program correctness; or (3) the act of reviewing, inspecting, testing, checking, auditing, or otherwise establishing and documenting whether items, processes, services, or documents conform to specified requirements.

**Waiver.** A documented authorization intentionally releasing a program or project from meeting a requirement. (Some Centers use waivers during the life cycle implementation phase, and deviations for the period prior to implementation.

**Work Agreement.** The Center form (or equivalent), prepared for each program/project cost account and used to document agreements and commitments for the work to be performed, including scope of work, receivables/deliverables, schedule, budget, and assumptions.

**Work Breakdown Structure (WBS).** A product-oriented hierarchical division of the hardware, software, services, and other tasks that organizes, displays, and defines the products to be developed and or produced and relates the elements of the work to be accomplished to each other and the end product(s). The WBS should reflect the way in which program/project costs, schedule, technical and risk data are to be accumulated, summarized, and reported. The WBS should be accompanied by a text document referred to as a WBS Dictionary that describes the work content of each element of the WBS in detail.

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## Appendix D ESSP Schedule Baseline

| Fiscal Year                    | 2006            |    |    |    | 2007            |    |    |    | 2008             |    |    |    | 2009             |    |    |    | 2010           |    |    |    | 2011            |    |    |    | 2012            |    |    |    | 2013        |    |    |    | 2014   |    |    |    | 2015           |  |  |  |  |  |  |  |
|--------------------------------|-----------------|----|----|----|-----------------|----|----|----|------------------|----|----|----|------------------|----|----|----|----------------|----|----|----|-----------------|----|----|----|-----------------|----|----|----|-------------|----|----|----|--------|----|----|----|----------------|--|--|--|--|--|--|--|
|                                | Q1              | Q2 | Q3 | Q4 | Q1              | Q2 | Q3 | Q4 | Q1               | Q2 | Q3 | Q4 | Q1               | Q2 | Q3 | Q4 | Q1             | Q2 | Q3 | Q4 | Q1              | Q2 | Q3 | Q4 | Q1              | Q2 | Q3 | Q4 | Q1          | Q2 | Q3 | Q4 | Q1     | Q2 | Q3 | Q4 |                |  |  |  |  |  |  |  |
| Program Implementation Reviews |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    | ▼  |                |    |    |    |                 |    |    | ▼  |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| PCA Updates†                   |                 |    |    |    |                 |    |    |    |                  |    |    | ▼  |                  |    |    |    |                |    |    |    |                 |    |    | ▼  |                 |    |    |    |             |    |    |    |        |    |    |    | ▼              |  |  |  |  |  |  |  |
| Solicitation Release*          |                 |    |    |    |                 |    |    |    |                  |    |    | ▼  |                  |    |    |    |                |    |    |    |                 |    |    | ▼  |                 |    |    |    |             |    |    |    |        |    |    | ▼  |                |  |  |  |  |  |  |  |
| Selection Announcement         |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    | ▼  |                |    |    |    |                 |    |    | ▼  |                 |    |    |    |             |    |    |    |        |    |    | ▼  |                |  |  |  |  |  |  |  |
| GRACE                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  | ←2002, Q2       |    |    |    | ▼ SR            |    |    |    |                  |    |    |    | ▼ SR             |    |    |    |                |    |    |    | ▼ SR            |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          | Primary Mission |    |    |    |                 |    |    |    | Extended Mission |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| CloudSat                       |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  | ▼ Launch        |    |    |    | ▼ SR            |    |    |    |                  |    |    |    | ▼ SR             |    |    |    |                |    |    |    | ▼ SR            |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    | Primary Mission |    |    |    |                  |    |    |    | Extended Mission |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| CALIPSO                        |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  | ▼ Launch        |    |    |    |                 |    |    |    | ▼ SR             |    |    |    |                  |    |    |    | ▼ SR           |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    | Primary Mission |    |    |    |                  |    |    |    | Extended Mission |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Aquarius                       |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  | ▼ CDR           |    |    |    | Inst. CDR       |    |    |    | ▼ CDR            |    |    |    |                  |    |    |    |                |    |    |    | ▼ Launch        |    |    |    | ▼ SR            |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    | Development      |    |    |    |                  |    |    |    |                |    |    |    | Primary Mission |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| OCO-2                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    | ▼ CDR          |    |    |    |                 |    |    |    | ▼ Launch        |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    | Formul.        |    |    |    | Development     |    |    |    | Primary Mission |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV Sub-Orbital                 |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  |                 |    |    |    |                 |    |    |    | ▼ Solicitation   |    |    |    | ▼ Award          |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    |                  |    |    |    | Formul.          |    |    |    | Development    |    |    |    | Primary Mission |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-1                           |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-3                           |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major Reviews                  |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    | ▼ Solicitation  |    |    |    | ▼ Award     |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    | Formul.     |    |    |    | Devel. |    |    |    |                |  |  |  |  |  |  |  |
| EV Orbital                     |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major reviews                  |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    | ▼ Solicitation |    |    |    |                 |    |    |    | ▼ Award         |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    | Formul.         |    |    |    | Development |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-2                           |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-4                           |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| Major reviews                  |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    | ▼ Solicitation |  |  |  |  |  |  |  |
| Phase                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV Instrument                  |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-I1                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    | Solicitation ▼ |    |    |    | Award ▼         |    |    |    |                 |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-I2                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    | Solicitation ▼  |    |    |    | Award ▼         |    |    |    |             |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |
| EV-I3                          |                 |    |    |    |                 |    |    |    |                  |    |    |    |                  |    |    |    |                |    |    |    |                 |    |    |    | Solicitation ▼  |    |    |    | Award ▼     |    |    |    |        |    |    |    |                |  |  |  |  |  |  |  |

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## Appendix E ESSP FY2011 Budget and Workforce Plans

**Table E-1: ESSP Budget As Included In the FY 2011 President's Budget Request**

| \$M                    | FY 2010<br>Enacted | FY 2011 | FY 2012 | FY 2013 | FY 2014 | FY 2015 |
|------------------------|--------------------|---------|---------|---------|---------|---------|
| Aquarius               | 18.3               | 17.0    | 5.4     | 5.2     | 2.4     | 4.6     |
| OCO-2                  | 25.0               | 171.0   | 91.0    | 51.0    | 13.0    | 4.0     |
| Venture Class Missions | 12.9               | 79.5    | 75.1    | 106.9   | 140.5   | 185.3   |
| CALIPSO                | 6.4                | 6.6     | 6.6     | 6.8     | 7.0     | 7.2     |
| GRACE                  | 4.8                | 5.2     | 4.9     | 5.0     | 5.1     | 5.3     |
| CloudSat               | 6.7                | 7.1     | 7.0     | 7.2     | 7.4     | 7.6     |
| ESSP Program Office    | 2.6                | 3.8     | 4.3     | 4.4     | 5.2     | 5.2     |
| ESSP Program Total \$M | 76.7               | 290.2   | 194.3   | 186.5   | 180.6   | 219.2   |

**Table E-2: ESSP Program PPBE 2011 Workforce Plan**

|                         | FY 2010 | FY 2011 | FY 2012 | FY 2013 | FY 2014 | FY 2015 |
|-------------------------|---------|---------|---------|---------|---------|---------|
| ESSP Program Office FTE | 6       | 10      | 12      | 12      | 12      | 12      |

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## Appendix F ESSP Program-Level Agreements

| Type of Agreement | Organizations                                  | Agreement Subject   | Approval Date |
|-------------------|--|---|---------------|
| ITA               | ESSP Program Office & DISCOVER-AQ PI           | Defines the work to be performed during the EV-1 Project in order to define and establish requirements for all life cycle phases. | 7/21/2010     |
| ITA               | ESSP Program Office & ATTREX PI                | Defines the work to be performed during the EV-1 Project in order to define and establish requirements for all life cycle phases. | 7/21/2010     |
| ITA               | ESSP Program Office & HS3 PI                   | Defines the work to be performed during the EV-1 Project in order to define and establish requirements for all life cycle phases. | 7/21/2010     |
| Task Plan         | ESD & JPL                                      | JPL to perform CARVE requirements development, implementation, and initial flight campaign.                                       | 8/26/2010     |
| Task Plan         | ESD & JPL                                      | JPL to perform AirMOSS project management activities, requirements development, and design.                                       | 8/26/2010     |
| Task Plan         | ESD & JPL                                      | JPL to perform CARVE Fourier Transformation Spectrometer procurements, science flight campaigns, and science data analysis        | 9/15/2010     |
| Task Plan         | ESD & JPL                                      | JPL to perform AirMOSS assembly, test, operations, and science analysis.  | 9/15/2010     |
| NSA               | GSFC Robotics System Protection Office & CONAE | GSFC RSPO to perform Conjunction Assessment Risk Analysis using USSTRATCOM data on behalf of CONAE for Aquarius/SAC-D Mission     | 10/26/2010    |

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## **Appendix G Gravity Recovery and Climate Experiment (GRACE)**

### **G.1 GRACE DESCRIPTION**

GRACE was selected from ESSP AO-1 and comprises twin satellites launched in March 2002. The GRACE satellites are making detailed measurements of Earth's gravity field that are leading to discoveries about gravity and Earth's natural systems. GRACE contributes to:

- Geodesy (defining an improved reference frame for defining position coordinates, better calculation of orbits for geodetic satellites, a more accurate equipotential surface to which land elevations can be referenced)
- Oceanography (enabling a better understanding of ocean currents and mass and heat transport)
- Climate (through ocean interactions, and mass changes in the atmosphere)
- The solid Earth (mass and gravity changes due to subduction zones, post-glacial rebound)
- Glaciology (tracking the changing mass of ice sheets)
- Hydrology (tracking changes in the storage of water on and beneath Earth's surface)
- Other components of the Earth system.

GRACE has completed its primary five-year mission and is currently in an extended mission phase. GRACE underwent Senior Reviews in 2007 and 2009, and is currently extended through FY 2011. GRACE is a joint partnership between the NASA in the United States and Deutsche Forschungsanstalt für Luft und Raumfahrt (DLR) in Germany. The PI is from the University of Texas Center for Space Research (UTCSR). JPL is responsible for project management.

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## **G.2 GRACE LEVEL 1 REQUIREMENTS**

Gravity Recovery and Climate Experiment (GRACE)

December 1, 2000

### **Level 1 Requirements for the Gravity Recovery and Climate Experiment (GRACE) Mission**

#### **1. SCOPE**

This appendix to the Earth Science Enterprise (ESE) Program plans identifies the mission, science and programmatic (funding and schedule) requirements imposed on the University of Texas Center for Space Research (UTCSR) and the Jet Propulsion Laboratory (JPL), having prime responsibility for the development and operations of the Gravity Recovery and Climate Experiment (GRACE) of the Earth System Science Pathfinder Program.

This document serves as the guideline for mission assessments conducted by NASA Headquarters during the Implementation Subprocess and is an aid in the determination of science mission success during mission operations. The Mission Definition and Requirements Agreement (MDRA) under contract NAS5-97213 is the authoritative document for the evaluation of mission success.

Program authority is delegated from the Associate Administrator for the Office of Earth Science (AA/OES) through the Goddard Space Flight Center (GSFC) Center Director to the Earth Probes Program Manager within the Flight Projects Directorate at GSFC.

The Principal Investigator (PI) at UTCSR is responsible for the overall success of the GRACE Mission and is accountable to the AA/OES for the scientific success and to the GSFC Center Director for the programmatic success. The GSFC Program Management Council (PMC) is the governing PMC for the GRACE Mission. The GSFC Center Director is responsible for certifying GRACE flight readiness to the Associate Administrator for Earth Science. The PI at UTCSR is responsible for the JPL effort in the design, development, test, and launch phases of the GRACE Mission, as well as coordinating the efforts of the Co-PI and the co-investigators. On-orbit operations conducted by DLR/GSOC will be responsive to the PI. The PI will use the set of approved co-investigators reflected in the proposal for the scientific investigation and data verification tasks. Any changes to this science team will be coordinated with the ESSP Project Office.

Changes to information or requirements contained in this document require approval by the Office of Earth Science, NASA Headquarters.

#### **2. SCIENCE DEFINITION**

##### **2.1 Baseline Science Objectives**



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The primary goal of the GRACE Mission is to obtain accurate global and high resolution models for both the static and the time variable components of the Earth's gravity field. This goal will be achieved by making accurate measurements of the inter-satellite range and range rate between two co-planar, low altitude and polar orbiting satellites, using a micro-wave tracking system. In addition, each satellite will carry geodetic quality Global Positioning System (GPS) receivers, a laser retro-reflector for satellite laser ranging and high accuracy accelerometers to enable accurate estimation of gravity field models.

The gravity field estimates obtained from data gathered by the GRACE Mission will provide, with unprecedented accuracy, integral constraints on the global mass distribution and its temporal variations. In the oceanographic community, the knowledge of the static geoid, in conjunction with satellite altimeter data, will allow significant advances in the studies of ocean heat flux, long term sea level change, upper oceanic heat content, and the absolute surface geostrophic ocean currents. Further, the estimates of time variations in the gravity field obtained from GRACE, in conjunction with other in-situ data and geophysical models, will help the science community unravel complex processes in oceanography (e.g. deep ocean current change and sea level rise), hydrology (e.g. large scale evapo-transpiration and soil moisture changes), glaciology (e.g. polar and Greenland ice sheet changes), and the solid Earth sciences.

## **2.2 Science Instrument Summary Description**

The GRACE Mission is unique with respect to science instruments. The differential influence of the gravity field is manifested as a difference in the orbital motion of the COM of each GRACE satellite. The distance change, and hence the gravity field variations, must be inferred from the phase change measurements made between the respective antenna phase centers on the two satellites using the K-Band Ranging Instrument. In essence, the two satellites themselves become the instrument.

The High Accuracy Inter-satellite Ranging System (HAIRS) provides measurements of the distance change. In addition, the SuperSTAR Accelerometers are used to measure the non-gravitational accelerations acting on the satellites. The Star Camera Assembly is used to measure satellite orientation. The GPS Turbo-Rogue Receiver and the Instruments Processing Unit (IPU) are used for digital signal processing, as well as measuring the distance change relative to the GPS satellite constellation. The Laser Retro-Reflector Assembly provides measurements of the GRACE satellite orbits relative to terrestrial tracking networks. In addition, the GPS Receiver is also used for secondary atmospheric occultation experiments.

## **3. PROJECT DEFINITION**

### **3.1 Project Organization & Management**

The GRACE Principal Investigator (PI), Prof. Byron Tapley of the University of Texas, Austin Center for Space Research (UTCSR), has established teaming arrangements with

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a Co-Principal Investigator, Prof. Christoph Reigber of the GeoForschungszentrum (GFZ), Germany; the Deutsche Forschungsanstalt für Luft und Raumfahrt (DLR), Germany; the Jet Propulsion Laboratory (JPL), Space Systems Loral (SS/L), the Astrium, GmbH, the Applied Physics Laboratory (APL) at Johns Hopkins University, Office National d'Études et de Recherches Aéronautiques (ONERA) and the Langley Research Center (LaRC) to implement the GRACE Mission.

## 3.2 Project Acquisition Strategy

The PI will have overall responsibility for the total mission, including the instrument, spacecraft, ground system, mission planning and operations, data processing and analysis, and data distribution. Prof. Tapley will be supported by experienced management and engineering teams, which have established close and efficient working relationships. The DLR and GFZ will work under an International Memorandum of Understanding (IMOU) between NASA and DLR in a no-exchange of funds agreement. The DLR/GSOC will provide mission operations. DLR will provide the launch vehicle and launch services. GFZ will provide the German Science Data Systems and the Co-PI who will lead the German science implementation effort and coordinate all elements of the German contributions. JPL provides project management and systems engineering through the launch and early orbit checkout phases. (Astrium GmbH) provides the spacecraft buses and environmental testing under contract to JPL. Space Systems Loral (SS/L) provides the Ka-band ranging system, attitude control algorithms and operations planning support under contract to JPL. ONERA provides the SuperSTAR accelerometer under contract to JPL.

## 4. PROGRAMMATIC REQUIREMENTS

### 4.1 Science Requirements

#### 4.1.1 Primary Objectives

The primary goal of the GRACE mission is to provide, with unprecedented accuracy, estimates of the global high-resolution models of the Earth's gravity field for a period of up to 5 years. A temporal sequence of approximately monthly estimates of the gravity field provides the mean (or static) gravity field, as well as a time history of its temporal variability. An additional science objective of the GRACE mission is to provide several hundred globally distributed profiles each day of the excess delay, or bending angle of the GPS measurements due to the ionosphere and the atmosphere, using GPS limb sounding.

During mission operations, the GRACE science data shall be made available to the scientific community in an EOS compatible format, shortly after calibration and validation. The Level-1 data products include line of sight range change between the satellites measured using the K-band ranging instrument, the non-gravitational accelerations measured using the accelerometer, the GPS navigation data, as well as

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related ancillary data. The Level-2 data products include the coefficients of the geopotential fields, the satellite position and velocity, as well as excess delay and refractivity estimates from GPS limb sounding.

#### 4.1.2 Typical Science Applications

The estimates of the Earth gravity field from GRACE, in conjunction with other space-based measurements, in-situ data and geophysical models, will be used to discriminate time varying changes in the mass of the Earth's dynamical system due to different geophysical processes. Examples include the discrimination of effects due to sea level rise, continental water storage, ice sheet changes and other geophysical phenomena. Additionally, atmospheric model studies will benefit by the recovery of refractivity (and the derived quantities of temperature and water vapor) from the use of GPS limb sounding. Furthermore, limited GPS sounding of the ionosphere beginning at altitudes in the region of 100 km will be available for studying fine ionospheric structure.

As an example, Table 1 summarizes the areas in Earth System Science which will benefit from the geopotential field models estimated using GRACE measurements and other in-situ data and geophysical models. For each scientific application, the principal spatial, and where appropriate, the temporal scales of associated geoid variability are given for which GRACE is expected to have an impact. The accuracy of these determinations will depend on the methods of solution of complex geophysical inverse problems, taking into account not only the GRACE measurement errors but also the errors in the ancillary geophysical model and in-situ data (e.g. atmospheric or ocean tide models).

**Table 1 Science Applications Summary**

| APPLICATION                 | RESOLUTION | TIME SCALE          | COMMENTS                           |
|-----------------------------|------------|---------------------|------------------------------------|
| STATIC GRAVITY FIELD        |            |                     |                                    |
| Oceanic Heat Flux           | > 1000 km  |                     |                                    |
| Ocean Currents              | > 1000 km  |                     |                                    |
| Solid Earth Sciences        | > 300 km   |                     |                                    |
| TIME VARIABLE GRAVITY FIELD |            |                     |                                    |
| Oceanic Heat Flux           | > 1000 km  | Seasonal            | 30 day estimate                    |
| Ocean Bottom Pressure       | > 500 km   | Seasonal            | 30 day estimate                    |
| Deep Ocean Currents         | > 500 km   | Seasonal            | 30 day estimate                    |
| Sea Level Rise              | > 700 km   | Secular             | 5 year estimate                    |
| Evapo-Transpiration         | > 300 km   | Seasonal            | 30 day estimate                    |
| Greenland/Antarctic Ice     |            | Secular<br>Seasonal | 5 year estimate<br>yearly estimate |

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### 4.1.3 Baseline Science Mission Requirements

In the Baseline Science Mission definition, the Earth's geopotential field is characterized by the coefficients of a spherical harmonic expansion. These coefficients will be estimated to degree and order 160 or more for the long term mean part, and to degree and order 100 or less for the time variable part. The temporal variability will be characterized by mean values of the coefficients over 30 days or less. In addition, approximately 200 GPS atmospheric profile soundings per day shall be acquired, subject to data system limitations.

The science data, in conjunction with ancillary data, will be used to obtain estimates of spherical harmonic coefficients of the Earth's gravitational potential. A typical 30 day span of data, collected in a 475 km altitude polar orbit, shall have a global root mean square (rms) geoid height error due to the measurement system errors as specified in Table 2.

Table 2 Geoid Height Error over 30 days

| <u>Harmonic Degree</u> | <u>Geoid Height Error<br/>Per Degree<br/>(mm)</u> | <u>Geoid Height Error<br/>Cumulative (from n=3)<br/>(mm)</u> |
|------------------------|---|--|
| N = 2                  | < 0.10  | --   |
| 3 < n < 10             | < 0.01  | < 0.02   |
| 10 < n < 70            | < 0.15  | < 0.40   |
| 70 < n < 100           | < 1.50  | < 3.50   |
| 100 < n < 150          | < 65.0  | < 200  |

### 4.1.4 Minimum Science Mission Requirements

As a minimum objective for a successful mission, the GRACE measurements shall provide for at least an order of magnitude improvement in the mean global geoid. This improvement in the marine geoid will enhance dramatically the recovery of the general ocean circulation and ocean heat flux from satellite altimetry. Such improvement is a current requirement of both Earth Observation System (EOS) and World Ocean Circulation Experiment (WOCE).

For the Minimum Science Mission, the mean geopotential model will be characterized by a spherical harmonic model to at least degree and order 100. The cumulative contribution to global geoid height error from harmonic coefficients to degree and order 70 shall not exceed 1 cm rms. No atmospheric and ionospheric occultation data products will be available.

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#### 4.1.5 Science Measurement Objectives

The data required to realize the science goals are defined in Table 3, which establishes the primary measurement objectives for GRACE.

**Table 3 Science Measurement Objectives**

| Science                 | Measurement                  | Instrument                 | Spacecraft |
|-------------------------|------------------------------|----------------------------|------------|
| Earth Gravity Field     | Inter-Satellite Range Change | K-Band Ranging m-wave link | 2          |
|                         | Non-Grav. Accelerations      | Accelerometer              | 2          |
|                         | GPS Tracking Data            | GPS Receiver               | 2          |
| Atmospheric Occultation | GPS-to-GRACE phase change    | GPS Receiver               | 1          |

#### 4.2 Mission and Spacecraft Performance Requirements

The two GRACE spacecraft shall be designed for a five-year lifetime. The two GRACE satellites shall be in co-planar orbits at approximately 300-500 km altitude, at an inclination of 89 degrees, separated along track by approximately 100-500 km.

The data rates will be up to 20 Mb/day for the gravity field, and 20-40 Mb/day for the occultation experiment. Orbit maneuvers will be required every 30-60 days in order to maintain the separation between the satellites, in addition to the occasional calibration and altitude make-up maneuvers.

#### 4.3 Launch Requirements

The GRACE Mission is planned to launch in November 2001 from the Plesetsk Cosmodrome in Russia. There is no science window for the GRACE Mission.

The GRACE spacecraft will be launched into a near 500 km circular orbit at an inclination of 89 degrees.

#### 4.4 Ground Systems Requirements

The GRACE Mission Operations System shall be capable of acquiring and processing an average of at least 50 Mbytes of science and housekeeping data per day for each satellite.

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## **4.5 Mission Data Requirements**

### **4.5.1 Science Data Management**

The Science Data System (SDS) activities include data processing, verification, distribution, and archiving of science data. The SDS is a distributed entity, with some functions occurring at each of JPL, GFZ and UTCSR. Unification of data and product archives is planned, as well as comparison and validation activities. The PI is responsible for coordinating the development and management of the SDS.

### **4.5.2 Analysis Software**

Science analysis software shall be developed by the GRACE Science Data System Team. The Level-0 data system will be at DLR/GSOC, the Level-1 data system will be at NASA/JPL, and the Level-2 data system will be at UTCSR. A back-up Level-1 and Level-2 data system will be established in files at GFZ.

### **4.5.3 Data Management Plan**

A Mission Operations and Data Management Plan shall be developed to address the flow of science data, from acquisition, through processing, data product generation and validation to archiving and preservation.

## **4.6 Programmatic Milestones**

The following programmatic milestones are planned for the GRACE mission:

Mission Confirmation Review - November, 1998  
Mission Readiness Review – Third Quarter, 2001  
Launch Readiness Review – Fourth Quarter, 2001  
Launch - Fourth Quarter, 2001  
Initial Receipt of Data – Second Quarter, 2002  
Release of Calibrated Data to Broad User Community – Fourth Quarter, 2002

## **5. NASA MISSION COST REQUIREMENTS**

### **5.1 Cost Cap**

The GRACE Mission shall be undertaken on a “design to cost” basis. The GRACE mission shall be accomplished with a cost to NASA of no more than \$93,223,503.

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## **5.2 Cost Management and Scope Reduction**

The GRACE Mission has undergone extensive studies during Phase B and developed comprehensive risk mitigation strategies for key technical and programmatic risk items. In addition, the PI and PM have built an acceptable cost reserve pool to be used, when needed, to preserve the Baseline Science Mission. Use of this cost reserve is at the discretion of the PI, without further NASA approval. Should it become necessary to descope the Baseline Science Mission, the PI and his mission team will consult with the ESSP Project Office and NASA Headquarters before implementation. The Risk Management Plan and Descope Plan are fully described in the GRACE Cooperative Project Plan.

## **6. MULTI-MISSION NASA FACILITIES**

The GRACE Mission will utilize the PODAAC at JPL or another acceptable archive for science data archiving, as well as several NASA ground stations for launch, early orbit and contingency operations support.

## **7. EXTERNAL AGREEMENTS**

The DLR and GFZ are working on the GRACE Mission under the auspices of an International Memorandum of Understanding between NASA and the DLR. Both the DLR and GFZ confirmed that all necessary funds and resources have been committed for the GRACE Mission.

## **8. PUBLIC OUTREACH AND EDUCATION**

The GRACE Mission has developed and shall execute an Education and Public Outreach Plan. The outreach efforts are coordinated by the Texas Space Grant Consortium (TSGC).

## **9. SPECIAL INDEPENDENT EVALUATION**

The GRACE Mission has successfully completed the Mission Design Review and Mission Confirmation Review. Both of these reviews were staffed with reviewers independent of the GRACE Mission. The GRACE Systems Review Plan includes several independent reviews throughout the Implementation Subprocess.

## **10. TAILORING**

The GRACE Cooperative Project Plan (GRACE Project 327-100) details all tailoring of NPG 7120.5.

## **11. REQUIRED APPROVALS**

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Goddard Space Flight Center

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### G.3 GRACE 2009 SENIOR REVIEW

National Aeronautics and  
Space Administration  
**Headquarters**  
Washington, DC 20546-0001



SEP - 1 2009

Reply to Attn of: **SMD/Earth Science Division**

**TO:** University of Texas/GRACE Principal Investigator  
Jet Propulsion Laboratory/GRACE Project Manager

**FROM:** Director for Earth Science

**SUBJECT:** Results from the 2009 Senior Review of Earth Science Operating Missions

This letter provides programmatic direction for the Gravity Recovery and Climate Experiment (GRACE) mission for Fiscal Years (FY) 2010-2013, based on the findings of the 2009 Earth Science Division (ESD) Senior Review. To complete the Senior Review process, you must develop a plan responsive to the directions of this letter, and forward it to ESD/Cheryl Yuhas by COB on September 30, 2009, for review, possible modification and final acceptance.

The ESD Senior Review consisted of a series of comprehensive reviews of the missions' science quality, operational utility, and continued engineering performance of both spacecraft and instrument. A full description of the evaluation process, the factors used by the review panels, and their findings for all missions, may be found in the Senior Review Final Report, located at URL [http://nasascience.nasa.gov/earth-science/mission\\_list](http://nasascience.nasa.gov/earth-science/mission_list).

The review panels' findings for the GRACE mission are:

|                                 |             |
|---------------------------------|-------------|
| Science Value                   | Outstanding |
| Operational and Applied Utility | Very High   |
| Technical & Cost Risk           | Medium      |

(As noted in the 2009 Senior Review Call Letter, Education and Public Outreach (E/PO) is being considered separately from the Senior Review.)

The Science Panel recognized that the GRACE science mission has demonstrated significant technological and new scientific achievements. GRACE provides a unique measure of Earth's temporal gravity field, which includes climate-change signals. No other current satellite provides this type of measurement. The scientific achievement is truly cross-disciplinary, covering a broad range of NASA's Earth Science priority areas, including climate change, terrestrial water storage including groundwater variability, cryospheric changes, ocean circulation and sea level, and geodynamics. Although the National Interests Panel rated GRACE as "Very High Utility," primarily due to its critical contribution to the National Vertical Datum effort, the Science Panel believes additional applications science would be both possible and valuable, and supports the proposed new low-latency data product to satisfy

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hydrologic community requirements. The Technical and Cost Panel rated the mission extension as "Medium Risk," based on the loss of redundancy in several components, but also on the programmatic dependency on the international partner to operate the satellite.

I have used the panel's assessment in formulating the mission programmatic directions for the FY 2010-2013 period. These new guidelines, together with the scope of activities defined in this letter, constitute the new project level one requirements for the extended mission.

Your response to this direction should be in the form of a letter; the letter should include your project's response to the technical guidance below, a discussion of the Science Panel's assessment of your proposal's weaknesses, your project's plans to address those weaknesses, and the budget breakdown using the attached template.

General direction to all projects for E/PO and for efficiency metric reporting will come separately; your responses to these separate directions must be consistent with your response to the guidance in this letter. Dr. Ming-Ying Wei will be issuing the E/PO call simultaneously with this letter; efficiency metric reporting will be handled via e-mail from Cheryl Yuhas and Jennifer Kearns.

All missions are requested to provide an updated End of Mission Plan to ESD by March 30, 2010. End of Mission Plans must be compliant with NASA policies NPR 8715.6a and NPD 8010.3B, and are expected to follow the standards specified in NASA-STD 8719.14.

Specific guidance for the GRACE mission is as follows:

*The GRACE Project is directed to implement mission extension for FY2010-2013 in accordance with its optimal proposal, that is, derive regional mass-on solutions and conduct mutual validation of regional and global solutions with external investigators. The GRACE Science Team is encouraged to explore additional applications science, and to foster its international partnership.*

#### **Funding Direction**

Funding guidelines for the GRACE mission are below. These numbers are in real year dollars and represent the new Headquarters guidance for the sum of the traditional mission operations and core data analysis lines.

| FY 2010     | FY 2011     | FY 2012     | FY 2013     |
|-------------|-------------|-------------|-------------|
| \$5,135,000 | \$5,239,000 | \$4,855,000 | \$4,973,000 |

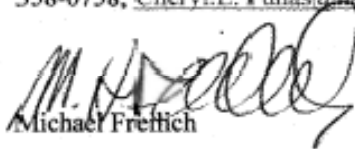
Your plan to meet these guidelines, including addressing any specific comments or redirection raised in this letter, should include a cost breakdown in the formats supplied in the attached budget template. While these guidelines are at the top mission level, it is my expectation that the distribution by Center/Workforce Breakdown Structure will be roughly equivalent to the allocations presented in the proposal.

It is our intention that the guidelines provided are the funds that will be made available to you in FY 2010 and FY 2011, but we note that changes in available resources and the requirements

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placed on us require revisiting budget allocations annually, or more frequently as circumstances warrant. If for some reason we believe that the resources to be available will differ from those indicated above, we will let you know as soon as we can. Guidelines for FY 2012 and FY 2013 should be considered preliminary, to be revisited during the 2011 ESD Senior Review.

I congratulate you and your team on the positive review results, and look forward to your response on September 30, 2009. Any questions may be directed to Ms Cheryl Yuhas, 202-358-0758, [Cheryl.L.Yuhas@nasa.gov](mailto:Cheryl.L.Yuhas@nasa.gov).

  
Michael Freilich

cc:

NASA HQ/J.Kaye

- J. Labrecque
- S. Volz
- C. Yuhas
- M. Wei

LaRC/E. Grigsby

JPL/D. Evans

- J. Graf
- M. Watkins
- M. Fujishin
- D. Vane

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## **Appendix H Cloud Aerosol LIDAR and Infrared Pathfinder Satellite Observations (CALIPSO)**

### **H.1 CALIPSO DESCRIPTION**

The CALIPSO mission is the culmination of a decade-long and continuing collaboration between NASA and the French Space Agency Centre National d'Études Spatiales (CNES). Since launch on April 28, 2006, CALIPSO has been providing nearly continuous measurements of the vertical structure and optical properties of clouds and aerosols in the Earth's atmosphere. These measurements provide new information and unique insights that will improve our understanding of the distribution and properties of clouds and aerosols, and markedly improve the performance of a variety of models ranging from regional chemical transport and weather forecast models to global circulation models used for climate prediction. The CALIPSO instrument suite consists of a two-wavelength polarization-sensitive LIDAR, a three-channel infrared imaging radiometer, and a single channel wide-field-of-view camera. CALIPSO maintains formation with other spacecraft in the A-Train satellite constellation and provides complementary, near-simultaneous, observations with the other active and passive instruments in the A-Train. CALIPSO has completed its nominal 3-year mission and is currently in its extended mission phase through FY 2011. The PI is from LaRC, and LaRC is responsible for project management.

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## **H.2 CALIPSO LEVEL 1 REQUIREMENTS**

# **LEVEL I REQUIREMENTS**

**for the**

# **CALIPSO MISSION**

**June 18, 2002**

**Revision A  
March 12, 2005**

|  |                            |             |
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### Document Revision Record

| <b>Revision</b> | <b>Date</b> | <b>Description of Change</b>  | <b>Approved By</b> |
|-----------------|-------------|---|--------------------|
| A               | 2005/03/12  | <p>Title Page: Added Revision A and generation date</p> <p>Section 1.1: Changed references to Earth Science Enterprise to the Science Mission Directorate.</p> <p>Section 2.1: Changed the total cost of the mission from \$151M to \$199M. This includes two separate replans, one for the increase in the Spring of 2004, from \$151M to \$186.6M, and the second in the Spring of 2005, to \$199M. The first increase also included adjustments required to convert to full cost accounting.</p> <p>Section 2.2: Changed the "Launch Readiness Date from 04/04 to Summer 2005.</p> <p>Section 2.2: Changed the Distribution of Cal/Val Data from 12/05 to Spring 2007.</p> <p>Section 3.1, Table 1: Deleted the two data products for Surface LW fluxes and Atmospheric LW fluxes. These products required the delivery of CERES data products to CALIPSO. Earth science R&amp;A budget reductions eliminated the incoming CERES analyses, and the CALIPSO project could not accommodate the increase.</p> <p>Section 3.3: Changed the launch ready date from April 2004 to Summer 2005.</p> <p>Section 3.6: Added mission success criteria.</p> <p>Section 5: Changed Ghassem Asrar to Alphonso Diaz as the responsible AA, and replaced references to the Earth Science directorate to the Science Mission Directorate</p> |                    |
|                 | 2005/05/25  | Section 2.2: Added a distribution of calibrated level 1b and level 2a data products by Launch + 180 days to the requirements.   |                    |

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## **LEVEL I REQUIREMENTS FOR THE CALIPSO MISSION**

### **1. OVERVIEW**

#### **1.1 SCOPE**

This document identifies the mission, science and programmatic requirements imposed on CALIPSO mission. This document establishes Headquarters' requirements for the implementing center. It serves as the basis for mission assessments conducted by NASA Headquarters during the Implementation Subprocess and provides the baseline for the determination of science mission success during mission operations.

Changes to the requirements specified in this document must be made through the following methods:

- Changes to scientific/technical/cost content require Science Mission Directorate (SMD) Directorate Program Management Council (DPMC) approval.
- Changes to cost requirements may be handled as a part of the POP process.
- Changes to the baseline launch readiness date require SMD DPMC approval and a letter of direction from the Associate Administrator for the Science Mission Directorate (AA/SMD).

Program authority is delegated from the Associate Administrator for Science Mission Directorate (AA/SMD) through the Goddard Space Flight Center (GSFC) Center Director to the Earth Explorers Program Manager for the successful implementation of the mission.

#### **1.2 PROJECT DEFINITION**

CALIPSO is a satellite mission designed to provide global measurements of aerosols and clouds required for better understanding of their role in the climate system and to improve our ability to predict long-term climate change and seasonal-to-interannual climate variability.

#### **1.3 SCIENCE OBJECTIVES**

The primary science goal of CALIPSO is to acquire a global set of aerosol and cloud observations over a period of three years which, by themselves and in combination with coincident observations from the Aqua and CloudSat platforms, will allow significant advances in our understanding of the role of aerosols and clouds in the climate system. The mission has defined four primary science objectives and one secondary science objective.

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- Provide a global suite of measurements from which the first observationally based estimates of direct aerosol forcing, and its certainty, can be made.
- Enable the first global observationally-based assessment of indirect aerosol radiative forcing.
- Improve the accuracy of satellite estimates of longwave radiative fluxes at the surface of the Earth and longwave heating rates within the atmosphere by a factor of 2.
- Provide a new ability to assess cloud feedback in the climate system, including thin cirrus, polar clouds, and multi-layered cloud systems, all of which are poorly determined by passive radiometers alone.

A secondary objective is to provide a set of simultaneous coincident data with which to validate and improve data retrievals from NASA's Earth Observing System (EOS) Aqua mission.

## **2 PROGRAM REQUIREMENTS**

### **2.1 BUDGET REQUIREMENTS**

The total cost for the CALIPSO mission is \$199M, and includes NASA mission development, science, operations, and launch costs.

### **2.2 SCHEDULE REQUIREMENTS**

| <u>Milestone</u>  | <u>Completion Date</u> |
|---|------------------------|
| Launch Readiness Date   | Summer 2005            |
| Distribution of calibrated level 1b and 2a data products (lidar profiles, IIR and WFC radiances, meteorological profiles, lidar aerosol/cloud browse images and backscatter profiles, aerosol layer and cloud height/thickness) | Launch + 180 days      |
| Distribution of Cal/Val Data  | Spring 2007            |

### **2.3 EXTERNAL AGREEMENT REQUIREMENTS**

In accordance with Article III of the NASA/CNES MOU, and in summary, CNES is responsible for providing science team participation, IIR algorithm development, the PROTEUS platform, satellite engineering, Imaging Infrared Radiometer, payload-to-platform integration and test, the command and control data uplink for the satellite, the satellite operations and control center, and support satellite-to-launch vehicle integration and test.

### **2.4 MULTI-MISSION FACILITIES REQUIREMENTS**

The CALIPSO mission will use the LaRC Distributed Active Archive Center (DAAC) for data processing, archive and distribution. Funding for data processing and archive activities is included in the CALIPSO budget.



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## 2.5 CONSTRAINTS

N/A

## 3. PERFORMANCE REQUIREMENTS

### 3.1 MISSION REQUIREMENTS

The science objectives will be achieved by flying the lidar, the Imaging Infrared Radiometer (IIR), and a wide field camera (WFC) in formation with Aqua for a three-year mission life. Science requirements can still be met if the IIR and/or WFC are operated discontinuously during the third year of the on-orbit mission to meet power constraints, if required.

The CALIPSO orbit requirements of 705 km altitude with a 1:30 pm equator crossing time are derived from the science requirement for coincident measurements with Aqua and the Aqua orbit. Constellation flying with Aqua will be implemented to ensure science objectives are met, and to ensure safe operations with Aqua and other missions in the proposed Aqua train.

The science data products and associated measurement uncertainties required to realize the mission objectives are defined in Table 1.

**Table 1. Science Products and Uncertainties**

| Data Product  | Measurement Capabilities and Uncertainties |
|---|--|
| <b>Aerosols</b>   |  |
| Height, thickness   | For layers with $\tau > 0.005$             |
| $\tau$ , $\sigma(z)$  | 40%**                                      |
| <b>Clouds</b>   |  |
| Height  | For layers with $\tau > 0.01$              |
| Thickness   | For layers with $\tau < 5$                 |
| $\tau$ , $\sigma(z)$  | Within a factor of 2 for $\tau < 5$        |
| Ice/water phase   | Layer by layer                             |
| Ice cloud emissivity, $\epsilon$  | $\pm 0.03$                                 |
| Ice particle size   | $\pm 50\%$ for $\epsilon > 0.2$            |
|   |  |
|   |  |
| $\tau$ - optical depth<br>$\sigma(z)$ - profile of extinction cross-section<br>**assumes 30% uncertainty in backscatter-to-extinction ratio |  |

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### 3.2 INSTRUMENT INFORMATION

The CALIPSO instrument suite and measurements required to achieve the science baseline objectives are described below:

- The lidar acquires vertical profiles of elastic backscatter at 532 and 1064 nm from a near nadir viewing geometry during day and night segments of the orbit. Two orthogonal polarization components (parallel and perpendicular to polarization plane of the transmitted beam) are measured at 532 nm. The lidar profiles provide information on the vertical distributions of aerosols and clouds, cloud particle phase (via the ratio of signals in the two orthogonal polarization channels at 532 nm), and classification of aerosol size (via wavelength dependence of backscatter).
- The IIR provides medium spatial resolution, nadir-viewing images at 8.65  $\mu\text{m}$ , 10.6  $\mu\text{m}$ , and 12.05  $\mu\text{m}$ . The IIR operates continuously, night and day, providing information on cirrus cloud particle size and infrared emissivity, and allows nighttime verification of the co-registration of CALIPSO observations with those of Aqua.
- The WFC is a digital camera that collects high spatial resolution imagery in the 620-nm to 670-nm wavelength range during the daylight segments of orbit. The WFC spectral band is matched to MODIS channel 1. WFC data will be used for ascertaining cloud homogeneity to provide overall meteorological context, and to aid IIR retrievals. Also, the WFC images will be used for highly accurate daytime co-registration of CALIPSO observations with those of Aqua.

### 3.3 LAUNCH REQUIREMENTS

CALIPSO shall be launch-ready in Summer 2005 in a dual launch configuration with the CloudSat satellite. The launch vehicle will be the Boeing Delta II 7420-10C launch vehicle with a Dual Payload Attach Fitting (DPAF) with CALIPSO in the upper berth. CALIPSO and CloudSat shall be launched from Vandenberg Air Force Base (VAFB) in California.

### 3.4 MISSION OPERATIONS REQUIREMENTS

The CALIPSO satellite and ground systems shall be designed for a three-year on-orbit lifetime.

### 3.5 SCIENCE DATA SYSTEM REQUIREMENTS

CALIPSO shall use the LaRC DAAC to perform science Standard Products data processing, distribution, and archive.

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### 3.6 MISSION SUCCESS CRITERIA

Success for CALIPSO is defined as a significant improvement over our current knowledge of the global characteristics of multi-layer cloud structure and the vertical distribution of aerosols. CALIPSO observations will produce:

- 1) The first high resolution (60 m) global profiles of clouds and aerosols with a backscatter sensitivity of at least  $1 \times 10^{-3}$ /km/sr at 532 nm.
- 2) The first global high resolution (60 m) profiles of cloud ice/water phase.
- 3) A comprehensive data set including seasonal cloud and aerosol properties to be acquired over periods including 3 months each during summer and winter (Jun-Aug and Dec-Feb), and 2 additional months (April, October) in the spring and the fall.

As CALIPSO will be flying as part of the A-train, all measurements are expected to be coincident with other A-train satellite observations for the data to be available for processing and modeling efforts outside of the CALIPSO project.

## 4. PUBLIC OUTREACH AND EDUCATION REQUIREMENTS

The CALIPSO project shall develop and execute an Education and Public Outreach Plan. Activities will focus on communicating the CALIPSO mission and scientific results through informal and formal venues. These activities will include creation of CALIPSO content materials, development of education programs that amplify the efforts of CALIPSO and stimulate broad awareness and understanding, and the identification of new applications required to incorporate the rewards of CALIPSO into the fabric of our everyday life.

## 5. APPROVAL

*Original signed by G. Asrar for A. Diaz*

---

A. V. Diaz  
Associate Administrator for  
Science Mission Directorate

|  |                            |             |
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### H.3 CALIPSO 2009 SENIOR REVIEW

National Aeronautics and  
Space Administration  
**Headquarters**  
Washington, DC 20546-0001



SEP - 1 2009

Reply to A/E of: SMD/Earth Science Division

**TO:** Langley Research Center/CALIPSO Principal Investigator  
Langley Research Center/CALIPSO Project Scientist

**FROM:** Director for Earth Science

**SUBJECT:** Results from the 2009 Senior Review of Earth Science Operating Missions

This letter provides programmatic direction for the CALIPSO mission for Fiscal Years (FY) 2010-2013, based on the findings of the 2009 Earth Science Division (ESD) Senior Review. To complete the Senior Review process, you must develop a plan responsive to the directions of this letter, and forward it to ESD/Cheryl Yuhas by COB on September 30, 2009, for review, possible modification and final acceptance.

The ESD Senior Review consisted of a series of comprehensive reviews of the missions' science quality, operational utility, and continued engineering performance of both spacecraft and instrument. A full description of the evaluation process, the factors used by the review panels, and their findings for all missions, may be found in the Senior Review Final Report, located at URL [http://nasascience.nasa.gov/earth-science/mission\\_list](http://nasascience.nasa.gov/earth-science/mission_list).

The review panels' findings for the CALIPSO mission are:

|                                 |           |
|---------------------------------|-----------|
| Science Value                   | Very Good |
| Operational and Applied Utility | Some      |
| Technical & Cost Risk           | Low       |

(As noted in the 2009 Senior Review Call Letter, Education and Public Outreach (E/PO) is being considered separately from the Senior Review.)

The Science Panel recognized that the CALIPSO lidar sensor provides unique vertical information on clouds and aerosols, crucial to radiation feedback, cloud parameterization, polar stratospheric clouds and aerosols, and the marine boundary layer. CALIPSO shows excellent synergy with existing A-Train platforms and is heavily involved in generation of value-added fusion products. The mission data are additionally crucial as a bridge to future satellite lidar missions, and will be essential in exploring climate impacts of ENSO and PNA cycles. Having only recently completed its prime operations phase, the CALIPSO product maturity is still improving, as seen in the release of the Version 3 profile product including product errors. Fairly extensive preliminary validation efforts have been accomplished through aircraft underflights, but detailed analysis of errors in the Level 2 products must still be investigated.

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CALIPSO products are beginning to be implemented in retrospective mode by operational forecast agencies to evaluate their model forecast skills, but the long latency limits near-real-time applications, reflected in the "Some Utility" rating by the National Interests Panel. The "Low Risk" rating by the Technical and Cost Panel is based on the available subsystem redundancy, healthy margin in its propellant reserve, and even though one of the 2 lasers has failed, the performance so far of the second laser compared to the first indicates that the mission will remain healthy during the proposed mission extension.

I have used the panel's assessment in formulating the mission programmatic directions for the FY 2010-2013 period. These new guidelines, together with the scope of activities defined in this letter, constitute the new project level one requirements for the extended mission.

Your response to this direction should be in the form of a letter; the letter should include your project's response to the technical guidance below, a discussion of the Science Panel's assessment of your proposal's weaknesses, your project's plans to address those weaknesses, and the budget breakdown using the attached template.

General direction to all projects for E/PO and for efficiency metric reporting will come separately; your responses to these separate directions must be consistent with your response to the guidance in this letter. Dr. Ming-Ying Wei will be issuing the E/PO call simultaneously with this letter; efficiency metric reporting will be handled via e-mail from Cheryl Yuhas and Jennifer Kearns.

All missions are requested to provide an updated End of Mission Plan to ESD by March 30, 2010. End of Mission Plans must be compliant with NASA policies NPR 8715.6a and NPD 8010.3B, and are expected to follow the standards specified in NASA-STD 8719.14.

Specific guidance for the CALIPSO mission is as follows:

*The CALIPSO Project is directed to implement its extended mission in accordance with the optimal proposal. This includes the subsetting tool to improve data retrieval for the community. The project is requested to consider including the capability to search among multiple orbits allowing data merges to be implemented for a requested time interval. The project team is encouraged to continue its recent progress in exploring low-latency products and operational uses.*

#### **Funding Direction**

Funding guidelines for the CALIPSO mission are below. These numbers are in real year dollars and represent the new Headquarters guidance for the sum of the traditional mission operations and core data analysis lines.

| FY 2010     | FY 2011     | FY 2012     | FY 2013     |
|-------------|-------------|-------------|-------------|
| \$6,580,000 | \$6,654,000 | \$6,698,000 | \$6,888,000 |

Your plan to meet these guidelines, including addressing any specific comments or redirection raised in this letter, should include a cost breakdown in the formats supplied in the attached budget template. While these guidelines are at the top mission level, it is my expectation that

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the distribution by Center/Workforce Breakdown Structure will be roughly equivalent to the allocations presented in the proposal.

It is our intention that the guidelines provided are the funds that will be made available to you in FY 2010 and FY 2011, but we note that changes in available resources and the requirements placed on us require revisiting budget allocations annually, or more frequently as circumstances warrant. If for some reason we believe that the resources to be available will differ from those indicated above, we will let you know as soon as we can. Guidelines for FY 2012 and FY 2013 should be considered preliminary, to be revisited during the 2011 ESD Senior Review.

I congratulate you and your team on the positive review results, and look forward to your response on September 30, 2009. Any questions may be directed to Ms Cheryl Yuhas, 202-358-0758, [Cheryl.L.Yuhas@nasa.gov](mailto:Cheryl.L.Yuhas@nasa.gov).

  
Michael Freilich

cc:

NASA HQ/J.Kaye

- D. Considine
- S. Volz
- C. Yuhas
- M. Wei

LaRC/L. Vann

- E. Grigsby
- D. MacDonnell

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## **Appendix I CloudSat**

### **I.1 CLOUDSAT DESCRIPTION**

CloudSat provides the vertical distribution of cloud systems and their ice and water contents. CloudSat is acquiring the information needed by Numerical Weather Prediction (NWP) models and General Circulation Models (GCMs) to validate and improve their predictions of clouds. In addition, CloudSat provides the quantitative measurements of optical depth, layer thickness, base height, and ice and liquid water contents of clouds, facilitating accurate determination of the radiative properties of clouds and their roles in the radiative heating of the atmosphere. The knowledge of this heating is critical to improving understanding of cloud-climate feedback phenomena. CloudSat was launched in April 2006 and is flying in the A-Train constellation. CloudSat underwent Senior Reviews in 2007 and 2009, which extended the mission through FY 2011. In addition to NASA, contributing partners to CloudSat include the Canadian Space Agency (CSA), which provides radar components, and the U. S. Air Force Research, Development, Test and Evaluation Support Complex (RSC) at Kirtland Air Force Base, which provides the ground station network and conducts ground control of the satellite. The PI is from JPL, and JPL is responsible for project management.

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## **I.2 CLOUDSAT LEVEL 1 REQUIREMENTS**

# **LEVEL I REQUIREMENTS**

**for the**

**CloudSat MISSION**

**August 14, 2002**

**Revision A  
March 12, 2005**



|  |                            |             |
|--|----------------------------|-------------|
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#### Document Revision Record

| Revision | Date       | Description of Change   | Approved By                       |
|----------|------------|---|-----------------------------------|
| A        | 2005/03/12 | <p>Title Page: Added Revision A and generation date</p> <p>Section 1.1: Changed references to Earth Science Enterprise to the Science Mission Directorate.</p> <p>Section 1.2: added CALIPSO in formation and other satellites in constellation</p> <p>Section 2.1: Changed the total cost of the mission from \$140.2M to \$173M. This includes two separate replans, one for the increase in the Spring of 2004, from \$140.2M to \$168.1M, and the second in the Spring of 2005, to \$173M.</p> <p>Section 2.2: Changed the Launch Readiness Date from 04/04 to Summer 2005.</p> <p>Section 2.2: Changed the first release of validated data from 04/05 to Spring 2006.</p> <p>Section 2.3: Changed reference to a CSA-NASA MOU to a US-Canada agreement</p> <p>Section 3.3: Changed the launch ready date from April 2004 to Summer 2005.</p> <p>Section 3.6: Added mission success criteria.</p> <p>Section 5: Changed Ghassem Asrar to Alphonso Diaz as the responsible AA, and replaced references to the Earth Science directorate to the Science Mission Directorate</p> | <p>A. V. Diaz</p> <p>May 2005</p> |

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## LEVEL I REQUIREMENTS FOR THE CloudSat MISSION

### 1. OVERVIEW

#### 1.1 SCOPE

This document identifies the mission, science and programmatic requirements imposed on CloudSat mission. This document establishes Headquarters' requirements for the implementing center. It serves as the basis for mission assessments conducted by NASA Headquarters during the Implementation Subprocess, and it provides a basis for determining science mission success during mission operations.

Changes to the requirements specified in this document must be made through the following methods:

- Changes to scientific/technical/cost content require Science Mission Directorate (SMD) Directorate Program Management Council (DPMC) approval.
- Changes to cost requirements may be handled as a part of the POP process.
- Changes to the baseline launch readiness date require SMD DPMC approval and a letter of direction from the Associate Administrator for the Science Mission Directorate (AA/SMD).

Program authority is delegated from the Associate Administrator for Science Mission Directorate (AA/SMD) through the Goddard Space Flight Center (GSFC) Center Director to the Earth Probes Program Manager for the successful implementation of the mission.

#### 1.2 PROJECT DEFINITION

CloudSat is a space-mission experiment intended to measure the vertical structure of clouds with a radar from an earth-orbiting spacecraft. This radar is a millimeter-wave radar (94 GHz) capable of detecting a range of clouds from very thin cirrus to thick, precipitating thunderstorms. CloudSat will fly in a near-earth sun-synchronous orbit, in formation with CALIPSO and in a constellation other cloud-measuring satellites (viz. Aqua, Aura).

#### 1.3 SCIENCE OBJECTIVES

The primary science goal of CloudSat is to advance our understanding of the feedback between clouds and climate. Research investigations that utilize CloudSat data will be carried out through NASA NRA funded proposals and

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through contributions by other USA and non-USA organizations. The following are the science objectives that support the goal:

1. Quantitatively evaluate the representation of clouds and cloud processes in global atmospheric circulation models
2. Quantitatively evaluate the relationship between the vertical profiles of cloud liquid water and ice content and the radiative heating of the atmosphere and surface by the various cloud systems. This involves the following types of studies:
  - Evaluating the connection between cloud liquid water and ice contents and radiative properties
  - Comparing the heating rates derived with CloudSat data to those derived from the classes of models used to address Objective 1
  - Evaluating current approaches in estimating surface radiation fluxes
3. Evaluate cloud properties retrieved from other satellite systems, in particular those of Aqua

The Level 2 CloudSat Science Requirements document shall contain detailed measurements and measurement accuracy requirements.

## 2. PROGRAM REQUIREMENTS

### 2.1 BUDGET REQUIREMENTS

The total cost for the CloudSat mission is \$173M, and includes NASA mission development, science, operations, and launch costs.

### 2.2 SCHEDULE REQUIREMENTS

| <u>Milestone</u>                | <u>Completion Date</u>   |
|---------------------------------|--------------------------|
| Launch Readiness Date           | Summer 2005              |
| First release of validated Data | On or before Spring 2006 |

### 2.3 EXTERNAL AGREEMENT REQUIREMENTS

The Canadian Space Agency (CSA) is providing radar components to the CloudSat mission in accordance with government-to-government agreement between the United States and Canada. The USAF is providing ground network and mission operations services under a MOA between NASA GSFC and the USAF. Under a Cooperative Agreement with the PI, the DoE ARM Program is providing ground and airborne measurements to support the algorithm development and measurement validation activities.

### 2.4 MULTI-MISSION FACILITIES REQUIREMENTS

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The CloudSat mission will not use any NASA multi-mission facilities.

## 2.5 CONSTRAINTS

N/A

## 3. PERFORMANCE REQUIREMENTS

### 3.1 MISSION REQUIREMENTS

The science objectives are to provide from space the first global survey of cloud profiles and cloud physical properties, with seasonal and geographical variations, needed to evaluate the way clouds are parameterized in global models, thereby contributing to predictions of weather, climate and the cloud-climate feedback problem.

The spacecraft will be placed into a circular, sun-synchronous earth orbit for 22 months of continuous cloud observations, giving coverage over all latitudes (to within 8.2° of the poles) for 22 months. In addition, CloudSat will be flown on-orbit as part of the Aqua constellation.

The science data products required to realize the mission objectives are defined in Table 1.

**Table 1. CloudSat Data Products**

| Standard Data Product                                   | Measurement Accuracy   |
|---|--|
| Cloud classification & geometrical profile (Radar-only) | Detect all single-layer ice clouds with optical depth $\geq 1.0$ and all single-layer water clouds with optical depth $\geq 3.0$ ; Vertical resolution $\leq 550$ m from the surface to 25m above the mean geoid.  |
| Ice Water Content (Radar-only)                          | Ice content of non-precipitating clouds to +100%, -50% error, in $\leq 550$ m vertical layers;   |
| Liquid water content (Radar-only)                       | Liquid content of clouds to $\leq 50\%$ error in $\leq 550$ m layers.  |
| Radiative fluxes & heating rates                        | Estimates of in-cloud heating for each observed 550m cloud layer to within 1K day-1, km-1; Radiative forcing of clouds on longwave, downward, instantaneous radiative fluxes to $\leq 10\text{Wm}^{-2}$ (1-sigma). |

These measurement accuracies are those achievable by CloudSat as a standalone mission. CloudSat will fly in formation with and use data from Aqua and

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CALIPSO, which is expected to improve the measurement accuracy of CloudSat's data products.

### **3.2 INSTRUMENT REQUIREMENTS**

#### **3.2.1 Cloud Profiling Radar (CPR) Performance**

The vertical (range) resolution of the radar measurements will be  $500 \pm 50$  meters. The radar shall detect reflected signals with a sensitivity of  $\leq -26$  dBZ at end-of-life. The radar shall be calibrated to  $\pm 2.0$  dBZ pre-launch. The instantaneous radar footprint (IFOV) on the ground (FWHM) shall be  $\leq 2$  km along-track and  $\leq 2$  km cross-track. Radar sensitivity performance shall be based on a "science footprint" that is  $\leq 5$  km along-track and  $\leq 2$  km cross-track (FWHM).

### **3.3 LAUNCH REQUIREMENTS**

CloudSat shall be launch-ready in Summer 2005 in a dual launch configuration with the CALIPSO satellite. The launch vehicle will be the Boeing Delta II 7420-10C launch vehicle with a Dual Payload Attach Fitting (DPAF) with CloudSat in the lower berth. CALIPSO and CloudSat shall be launched from Vandenberg Air Force Base (VAFB) in California.

### **3.4 MISSION OPERATIONS REQUIREMENTS**

The CloudSat satellite and ground systems shall be designed for a two-year on-orbit lifetime.

### **3.5 SCIENCE DATA SYSTEM REQUIREMENTS**

CloudSat shall provide science data processing, including levels 1-N data processing, distribution, and data storage during the operational phase of the mission.

CloudSat will store Level 0-2 data products, along with the supporting ancillary data, and will transfer the CloudSat data set to the LaRC DAAC using the EOS-DIS HDF format at the conclusion of the mission.

### **3.6 MISSION SUCCESS CRITERIA**

The first set of global cloud measurements will be complete after one 16-day repeat of the groundtrack orbit. Each subsequent 16-day repeat cycle adds statistical information for cloud system types and seasonal changes. There are an estimated 40 such cycles in the 22 months of operations. Success for CloudSat is defined as the acquisition and processing of cloud radar measurements that will be used to greatly improve understanding of cloud physical properties and global characteristics of multi-layered cloud structures. To do this, CloudSat

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observations will produce on a global scale a significant improvement over current observational capability in these areas:

1. The first vertically resolved measurements and estimates of ice mass in clouds, with 500 m resolution an accuracy of 50% or better.
2. The first vertically resolved measurements and estimates of the liquid water content of clouds, with 500 m resolution and an accuracy of 30%.
3. The first estimates of the fraction of clouds producing precipitation, including all precipitation types (light or heavy, solid or liquid phase) as well as the clouds in which they occur.
4. The first resolved characteristics of vertical cloud structure.
5. The first observationally based estimates of vertical radiative heating by clouds, with 500 m vertical resolution, and to 1K/day.

#### 4. PUBLIC OUTREACH AND EDUCATION REQUIREMENTS

The CloudSat project shall develop and execute an Education and Public Outreach Plan. Activities will focus on communicating the CloudSat mission and scientific results through informal and formal venues. These activities will include creation of CloudSat content materials, development of education programs that amplify the efforts of CloudSat and stimulate broad awareness and understanding, and the identification of new applications required to incorporate the rewards of CloudSat into the fabric of our everyday life.

#### 5. APPROVAL

*- signed -*

Alphonso Diaz  
Associate Administrator for  
Science Mission Directorate

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### I.3 CLOUDSAT 2009 SENIOR REVIEW

National Aeronautics and  
Space Administration  
**Headquarters**  
Washington, DC 20546-0001



SEP - 1 2009

Reply to Attn of: SMD/Earth Science Division

TO: Colorado State University/CloudSat Principal Investigator  
Jet Propulsion Laboratory/CloudSat Project Manager

FROM: Director for Earth Science

SUBJECT: Results from the 2009 Senior Review of Earth Science Operating Missions

This letter provides programmatic direction for the CloudSat mission for Fiscal Years (FY) 2010-2013, based on the findings of the 2009 Earth Science Division (ESD) Senior Review. To complete the Senior Review process, you must develop a plan responsive to the directions of this letter, and forward it to ESD/Cheryl Yuhas by COB on September 30, 2009, for review, possible modification and final acceptance.

The ESD Senior Review consisted of a series of comprehensive reviews of the missions' science quality, operational utility, and continued engineering performance of both spacecraft and instrument. A full description of the evaluation process, the factors used by the review panels, and their findings for all missions, may be found in the Senior Review Final Report, located at URL [http://nasascience.nasa.gov/earth-science/mission\\_list](http://nasascience.nasa.gov/earth-science/mission_list).

The review panels' findings for the CloudSat mission are:

|                                 |           |
|---------------------------------|-----------|
| Science Value                   | Very Good |
| Operational and Applied Utility | High      |
| Technical & Cost Risk           | Low       |

(As noted in the 2009 Senior Review Call Letter, Education and Public Outreach (E/PO) is being considered separately from the Senior Review.)

The Science Panel recognized that CloudSat is satisfying its mission goals, following a logical validation program, producing data that are already being used in scientific discovery, and demonstrating its potential for future scientific productivity and operational use. Good science is already coming from the Cloudsat products; wider recognition of the value of these products will increase their use by the scientific and operational communities. The panel applauds the Principal Investigator's strategy to foster operational use by placing funded post-doctoral associates to work in the operational centers on integrating CloudSat information into their operational models. The potential to combine CloudSat measurements with measurement from other instruments in the A-Train, and its global coverage, make the CloudSat products unique. The instrument performance and data gathering statistics are all above required levels. The

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"High Utility" rating by the National Interests panel is based on the use by the few agencies familiar with its products for operational forecasts, as well model improvement. The "Low Risk" rating from the Technical and Cost panel is based on the nominal performance of the spacecraft and instrument, and the redundancy of the critical component in the Cloud Profiling Radar.

I have used the panel's assessment in formulating the mission programmatic directions for the FY 2010-2013 period. These new guidelines, together with the scope of activities defined in this letter, constitute the new project level one requirements for the extended mission.

Your response to this direction should be in the form of a letter; the letter should include your project's response to the technical guidance below, a discussion of the Science Panel's assessment of your proposal's weaknesses, your project's plans to address those weaknesses, and the budget breakdown using the attached template.

General direction to all projects for E/PO and for efficiency metric reporting will come separately; your responses to these separate directions must be consistent with your response to the guidance in this letter. Dr. Ming-Ying Wei will be issuing the E/PO call simultaneously with this letter; efficiency metric reporting will be handled via e-mail from Cheryl Yuhas and Jennifer Kearns.

All missions are requested to provide an updated End of Mission Plan to ESD by March 30, 2010. End of Mission Plans must be compliant with NASA policies NPR 8715.6a and NPD 8010.3B, and are expected to follow the standards specified in NASA-STD 8719.14.

Specific guidance for the CloudSat mission is as follows:

*The CloudSat Project is directed to implement its optimal proposal for mission extension, completing the precipitation products and developing the combined CloudSat/CALIPSO product, as proposed.*

#### **Funding Direction**

Funding guidelines for the CloudSat mission are below. These numbers are in real year dollars and represent the new Headquarters guidance for the sum of the traditional mission operations and core data analysis lines.

| FY 2010     | FY 2011     | FY 2012     | FY 2013     |
|-------------|-------------|-------------|-------------|
| \$7,071,000 | \$7,143,000 | \$6,999,000 | \$7,177,000 |

Your plan to meet these guidelines, including addressing any specific comments or redirection raised in this letter, should include a cost breakdown in the formats supplied in the attached budget template. While these guidelines are at the top mission level, it is my expectation that the distribution by Center/Workforce Breakdown Structure will be roughly equivalent to the allocations presented in the proposal.

It is our intention that the guidelines provided are the funds that will be made available to you in FY 2010 and FY 2011, but we note that changes in available resources and the requirements



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placed on us require revisiting budget allocations annually, or more frequently as circumstances warrant. If for some reason we believe that the resources to be available will differ from those indicated above, we will let you know as soon as we can. Guidelines for FY 2012 and FY 2013 should be considered preliminary, to be revisited during the 2011 ESD Senior Review.

I congratulate you and your team on the positive review results, and look forward to your response on September 30, 2009. Any questions may be directed to Ms Cheryl Yuhas, 202-358-0758, [Cheryl.L.Yuhas@nasa.gov](mailto:Cheryl.L.Yuhas@nasa.gov).



Michael Freilich

cc:

NASA HQ/J.Kaye

- D. Considine
- S. Volz
- C. Yuhas
- M. Wei

JPL/D. Evans

- J. Graf
- M. Fujishin

LaRC/E. Grigsby

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## **Appendix J Aquarius**

### **J.1 AQUARIUS DESCRIPTION**

Aquarius will make pioneering space-based measurements of Sea Surface Salinity (SSS) with the precision, resolution, and coverage needed to characterize salinity variations and investigate the linkage between ocean circulation, the Earth's water cycle, and climate variability. Salinity is required to determine seawater density, which in turn governs ocean circulation. SSS variations are governed by freshwater fluxes due to precipitation, evaporation, runoff, and the freezing and melting of ice. The Argentine Comisión Nacional de Actividades Espaciales (CONAE) is a partner on the project and is providing the SAC-D spacecraft bus, secondary science instruments, as well as the Mission Operations & Ground System. Aquarius was approved to proceed to Phase C in October 2005 and is planning to launch in 2011. The PI is from Earth and Space Research. JPL is responsible for project management during implementation, and GSFC takes over project management in the operations phase.

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## **J.2 AQUARIUS LEVEL 1 REQUIREMENTS**

### **Aquarius Project**

A NASA Earth System Science Pathfinder (ESSP) Mission

## **Level 1 Requirements and Mission Success Criteria**

Version: 2.0

Date: 10 November 2009

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## Change Log

| Revision | Date     | Sections Changed  | Author    |
|----------|----------|---|-----------|
| 2.0      | 11/10/09 | 2.2 – Clarified text; 3.1 – Clarification; 3.2 – Added information on the Operations Phase organization. 4.1.1 – Changed “ice-free oceans” to “open ocean”; 5.1 – Updated to currently approved funding level; 5.2.1.1 – Added to capture mission duration descope direction; 5.3 – Updated to currently approved launch readiness date; Figure 1 – Clarification; Figure 2 added. Approval/concurrence signatures updated. | E. Ianson |
|          |          |   |           |
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## 1. Scope

This document describes the Level 1 science, mission, schedule, and cost requirements governing the Earth System Science Pathfinder (ESSP) Aquarius mission. Level 1 Requirements serve as the basis for mission assessments conducted by NASA during the development period and provide the baseline for determining science mission success during the operational phase.

The Aquarius Principal Investigator (PI) is responsible for the overall success of the Aquarius Project, and is accountable to the Associate Administrator of the Science Mission Directorate (SMD). The Aquarius PI delegates the project implementation authority to the Director of the Jet Propulsion Laboratory (JPL), and the JPL Director has delegated this authority to the JPL Earth Science and Technology Directorate (ESTD) and the Aquarius Project Manager. The PI delegates operational phase responsibilities to the Director, Goddard Space Flight Center (GSFC). The Governing Program Management Committee is the NASA SMD Program Management Council.

The Aquarius mission is implemented jointly with the Argentina Comisión Nacional de Actividades Espaciales (CONAE). The CONAE mission is called SAC-D. This joint undertaking is referred to as the Aquarius/SAC-D Mission. Throughout this document, reference to Aquarius will specifically apply to the NASA ESSP Aquarius mission. Reference to Aquarius/SAC-D applies to the integrated NASA-CONAE mission. The implementation of Aquarius/SAC-D is governed by a Memorandum of Understanding (MOU) (see Section 5.4.1).

The Aquarius Level 1 requirements must remain consistent with the MOU. Any changes to the Level 1 requirements specified in this document must be approved by NASA SMD.

## 2. Science Definition

### 2.1. Science Objectives

The ESSP Aquarius Project will implement an Exploratory Measurement Mission designed to make pioneering space-based measurements of Sea Surface Salinity (SSS) with the precision, resolution, and coverage needed to characterize salinity variations and investigate the linkage between ocean circulation, the Earth's water cycle, and climate variability. Salinity is required to determine seawater density, which in turn governs ocean circulation. SSS variations are governed by freshwater fluxes due to precipitation, evaporation, runoff and the freezing and melting of ice. The Aquarius SSS measurements will be used to address two key areas of NASA's Earth Science research strategy described ESSP-3 Announcement of Opportunity (AO-01-OES-01):

**Earth System Variability and Trends:** How are global precipitation, evaporation, and the cycling of water changing?

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**Earth System Responses and Feedback Processes:** How can climate variations induce changes in the global ocean circulation?

In meeting these objectives, Aquarius will also validate a space-based measurement approach and analysis concept that could be used for future systematic SSS monitoring missions.

## ***2.2. Implementation Approach***

Space-based SSS measurements are required to provide systematic global mapping because the existing compilation of *in situ* ship and buoy observations is inadequate to meet the science objectives. The *in situ* spatial and temporal sampling is sparse, irregular and largely confined to shipping lanes and the summer season. About 25% of the world oceans have never been sampled, including vast regions of the southern hemisphere. More than 73% of the world oceans have fewer than 10 observations per one-degree square, insufficient to resolve the annual water cycle, interannual variability, or the spatial fronts, eddies and current systems that affect oceanographic circulation processes.

Aquarius will retrieve SSS by microwave remote sensing of surface brightness temperature at L-band, which is governed by the surface salinity, temperature and roughness (due to wind and waves). An integrated L-band microwave radiometer/scatterometer will be developed and deployed as the salinity measuring instrument, consisting of three beams in a pushbroom configuration. The radiometers will measure the L-band microwave surface brightness temperature and the radar scatterometer measurements will be used to derive the brightness temperature correction due to surface roughness. Ancillary measurements of surface temperature, surface wind and other geophysical corrections needed to convert brightness temperature to salinity will be obtained from other satellite observing systems and operational models. Aquarius will provide global sampling on an orderly, comprehensive, spatial and temporal pattern from a low earth orbiting satellite over the open ocean (defined in these requirements as the ocean regions where the microwave emissions are not significantly contaminated by land and ice surfaces which have much higher brightness temperature than the ocean). The observatory will be in a sun-synchronous orbit with the sensors oriented away from the sun to minimize contamination by the L-band solar radiation. Independent calibration and validation will be applied to verify SSS retrieval accuracy. SSS measurements will be provided in practical salinity units (psu) according the international standard Practical Salinity Scale (1978), which is based on seawater electrical conductivity, and is a very near approximation of salt concentration in g/kg.

The open ocean SSS range is ~32-37 psu, and the scale of seasonal-to-inter-annual variations can be as much as 1-2 psu in key regions. Modeling studies show that mapping the mean annual SSS to 0.2 psu accuracy over multiple seasonal cycles on spatial scales of 150 km x 150 km will, at a minimum, enable us to substantially reduce the large uncertainties in the mean global net air-sea freshwater flux, which constitutes ~80% of the global water cycle, and to quantify the associated links to oceanic mean

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circulation. The Baseline Science Mission enables study of the relevant oceanic processes on intraseasonal to interannual time scales by resolving the SSS with 0.2 psu accuracy on monthly time scales for at least three years. The Minimum Science Mission enables the study of these processes over an annual cycle by resolving the SSS with 0.2 psu accuracy on seasonal time scales for at least one year.

### 3. Project Definition

#### *3.1. Project Organization and Management*

The Aquarius/SAC-D Project includes US institutional partners that are funded by NASA and the international CONAE partnership that is without exchange of funds:

- NASA JPL responsibilities include the Aquarius mission implementation phase project management, Aquarius Project System Engineering; Aquarius Safety and Mission Assurance; Aquarius Instrument, including the scatterometer, antenna, command, data, and power subsystems; Aquarius Instrument integration and test; and data archive.
- NASA GSFC responsibilities include managing the Aquarius PI contract; Aquarius operations phase Project Management; Aquarius instrument radiometer subsystem; science algorithms, calibration and validation; and development and operations of the Aquarius ground data system including NASA-CONAE ground system interfaces.
- NASA Kennedy Space Center (KSC) is responsible for the launch services.
- CONAE responsibilities include development, integration, test and mission operations of the Aquarius/SAC-D observatory; SAC-D service platform; CONAE and third party instruments.

The Aquarius and SAC-D organizations for the implementation phase are shown in *Figure 1*. Key NASA and CONAE management and engineering interfaces for the Aquarius/SAC-D joint implementation are identified. The operational phase organizational changes are reflected in *Figure 2*. A Joint Steering Group, consisting of senior project and agency officials from both parties, provides overall guidance to the Project and decides any matters that affect the mission launch schedule, Level 1 mission requirements, and other implementation issues not resolved by the respective Project Managers.



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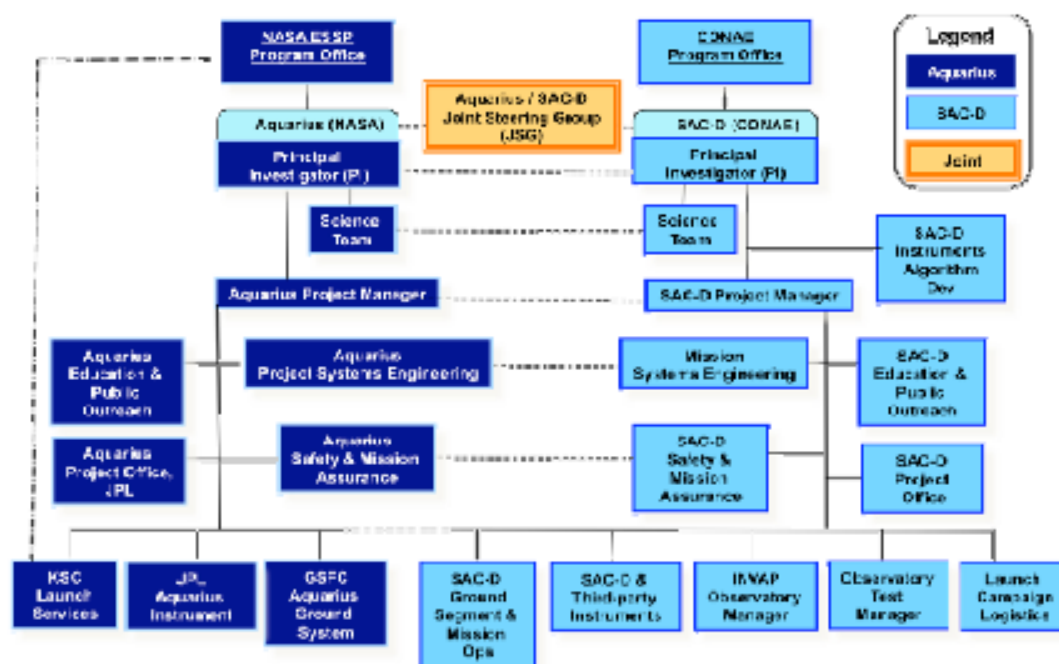


Figure 1: Block diagram showing the Aquarius and SAC-D organizations and their technical/programmatic interfaces during mission implementation phase.

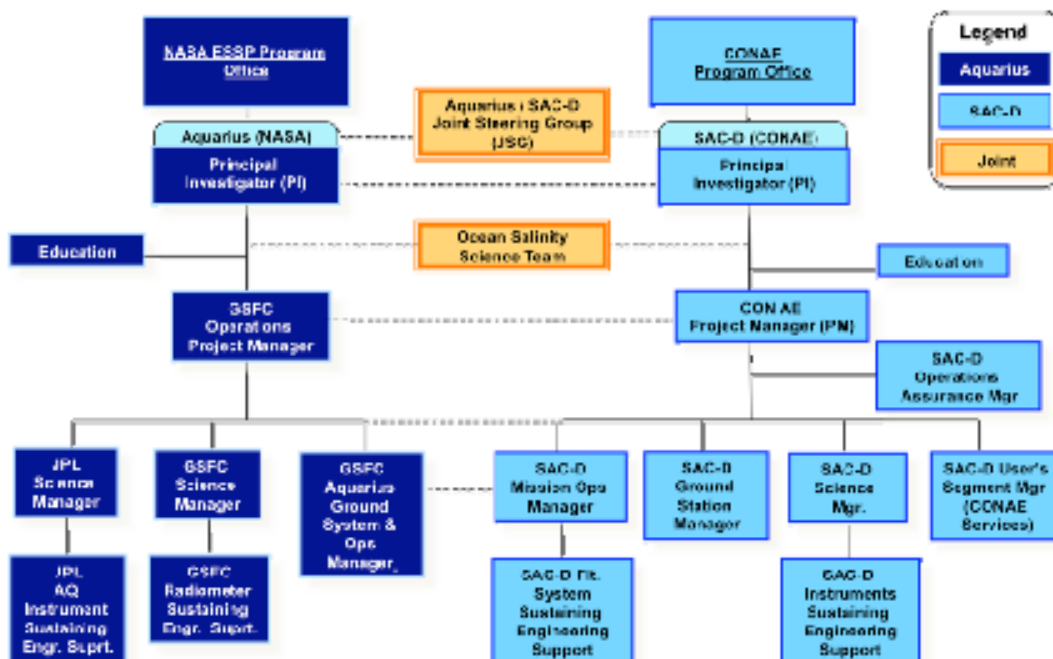


Figure 2: Block diagram showing the Aquarius and SAC-D organizations and their technical/programmatic interfaces during mission operation phase.

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### ***3.2. Project Acquisition Strategy***

The Aquarius/SAC-D project will be conducted using an observatory made up of the NASA provided Aquarius instrument, SAC-D science instruments, and the SAC-D spacecraft bus (service platform) contributed by CONAE. CONAE's SAC-D requirements are technically and scientifically compatible with Aquarius. The Aquarius/SAC-D mission operations will be conducted using an integrated mission operations system consisting of the CONAE observatory operations control center in Argentina, the GSFC Aquarius science planning and data processing center, and the JPL Physical Oceanography Distributed Active Archive Center (PO.DAAC) for data archive and distribution.

## **4. Performance Requirements**

### ***4.1. Science Requirements***

- 4.1.1. Requirement:** The Aquarius Mission shall collect the space-based measurements to retrieve SSS with global root-mean-square (rms) random errors and systematic biases no larger than 0.2 psu on 150 km by 150 km scales over the open ocean;
- 4.1.2. Requirement: The Baseline Science Mission shall:**
  - Be at least 3 years in duration.
  - Collect data sufficient to produce monthly mean estimates of SSS according to Requirement 4.1.1.
- 4.1.3. Requirement: The Minimum Science Mission shall:**
  - Be at least 1 year in duration.
  - Collect data sufficient to produce seasonal (3-month) mean estimates of SSS according to Requirement 4.1.1.

### ***4.2. Instrument Requirements***

- 4.2.1. Requirement:** The Aquarius instrument radiometers shall operate in the L-band frequency within the Earth Exploration Satellite Service (EESS) passive allocation 1400-1427 MHz.
- 4.2.2. Requirement:** The Aquarius instrument scatterometer shall operate in the L-band frequency EESS active allocation at 1.26 GHz.

### ***4.3. Observatory and Mission Operations Requirements***

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- 4.3.1. Requirement:** The Aquarius/SAC-D observatory shall fly in a sun synchronous polar Earth orbit that provides coverage to meet the science requirements in Section 4.1.
- 4.3.2. Requirement:** The Aquarius mission shall complete the In-Orbit Checkout (IOC) period within 90 days after launch, and then begin operations according to the science requirements in Section 4.1.

#### ***4.4. Launch Requirements***

- 4.4.1. Requirement:** NASA shall provide for the launch of the Aquarius/SAC-D observatory from the Vandenberg Air Force Base in California on a dedicated Delta 7320-10 launch vehicle.
- 4.4.2. Requirement:** The launch vehicle and launch services will be procured by NASA through the NASA Kennedy Space Center (KSC).

#### ***4.5. Science Measurement Validation Requirements***

- 4.5.1. Requirement:** The Aquarius validation program shall assemble and analyze conventional surface *in-situ* measurements from regional and global arrays for instrument calibration and data validation.
- 4.5.2. Requirement:** The *in situ* SSS measurements provided freely by the international Climate Variability (CLIVAR), Global Ocean Observing System (GOOS) Programs or other sources shall be obtained and used. These measurements are available in the public domain and require no external agreements between NASA and other institutions.
- 4.5.3. Requirement:** The Aquarius validation program shall demonstrate that retrievals of SSS meet the science requirements in Section 4.1.

#### ***4.6. Data Product Requirements***

The Aquarius Data Products are defined in Table 1.

**Table 1. Aquarius Data Products**

| Data Product | Description   |
|--------------|---|
| Level 1a     | Reconstructed Unprocessed Instrument Data               |
| Level 1b     | Calibrated Sensor Units                                 |
| Level 2      | Derived Geolocated SSS                                  |
| Level 3      | Time-space averaged SSS on a standard Earth Projection. |

- 4.6.1. Requirement:** No later than twelve (12) months after the end of the IOC period, the Aquarius Project shall deliver the first release of data products (containing at least six (6) months of data) in Table 1 to a NASA Distributed Active Archive Center (DAAC).

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- 4.6.2. **Requirement:** After the first release of validated Aquarius data, the Aquarius data products shall be delivered to the DAAC as soon as the validated data are available, but no later than six months after measurements are taken in orbit.
- 4.6.3. **Requirement:** The final data products produced by the Aquarius Project shall be delivered to the DAAC within six (6) months after the end of the prime mission.

## 5. Program Requirements

### 5.1. Budget Requirements

- 5.1.1. **Requirement:** The total NASA cost for the Aquarius mission shall include the formulation, implementation, launch, operations, calibration, validation, and science data analysis costs to generate the products in Table 1.
- 5.1.2. **Requirement:** The total direct NASA cost for the Aquarius mission shall not exceed \$270.3M.
- 5.1.3. **Requirement:** The Aquarius mission science investigations shall be augmented by an Ocean Salinity Science Team, funded through a NASA Research Announcement, no later than one year before launch. Funding for the Ocean Salinity Science Team shall not be included in the total NASA mission cost.

### 5.2. Cost Management and Scope Reduction

- 5.2.1. **Requirement:** Provided that due consideration has been given to the use of budgetary and schedule reserves, the Aquarius Project shall pursue scope reduction to control cost and mitigate risk. Any potential scope reductions that reduce the science capability from the Baseline Science Mission (section 4.1.1) shall be implemented only with the concurrence of NASA Headquarters and the ESSP Program Office.

### 5.3. Schedule Requirements

- 5.3.1. **Requirement:** The Aquarius Project shall target a Launch Readiness Date of December 2010

### 5.4. External Agreement Definition

- 5.4.1. **Requirement:** The Aquarius mission shall be conducted in conjunction with the Argentina space agency, CONAE, which will provide specific mission elements and services identified in an MOU between NASA and CONAE (signed 2 March 2004).

### 5.5. Multi-Mission Facilities Requirements

- 5.5.1. **Requirement:** NASA shall make available the NASA Near Earth Network for coverage of Aquarius/SAC-D launch, critical flight activities in-flight anomaly resolution, and back-up to the CONAE ground station.

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### ***5.6. Safety Requirements***

**5.6.1. Requirement:** The Aquarius project shall implement a safety and mission assurance plan.

## **6. Education and Public Engagement Requirements**

**Requirement:** The Aquarius Project shall develop and execute an Education and Public Engagement Plan that utilizes unique scientific and/or engineering aspects of the mission to inspire and motivate the Nation's students and teachers as well as to engage and educate the public. The activities shall aim to stimulate broad awareness and understanding of the role of ocean salinity in the Earth's climate and the links between ocean circulation and the water cycle. The plan shall be optimized for educational and cost effectiveness and build upon the resources and capabilities that NASA has accrued in education and public engagement.

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## **7. Mission Success Criteria**

### ***7.1. The Aquarius Mission will be considered fully successful if it:***

- Meets the baseline science requirements (see Section 4.1)
- Meets the data product requirements (see Section 4.6)

### ***7.2. The Aquarius Mission will be considered minimally successful if it:***

- Meets the minimum science requirements (see Section 4.1)
- Meets the data product requirements (see Section 4.6)

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## 8. Approvals

\_\_\_\_\_  
Edward Weiler  
Associate Administrator, Science Mission Directorate  
NASA Headquarters

\_\_\_\_\_  
Date

\_\_\_\_\_  
Charles Elachi  
Director, Jet Propulsion Laboratory

\_\_\_\_\_  
Date

\_\_\_\_\_  
Arthur Obenschain  
Director (Acting), Goddard Space Flight Center

\_\_\_\_\_  
Date

\_\_\_\_\_  
Edward Grigsby  
Program Manager  
Earth System Science Pathfinder Program

\_\_\_\_\_  
Date

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## 9. Concurrences

\_\_\_\_\_  
 Gary Lagerloef  
 Principal Investigator, Aquarius Mission  
 Earth and Space Research

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Amit Sen  
 Project Manager, Aquarius Mission  
 Jet Propulsion Laboratory

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Diane Evans  
 Director, Earth Science and Technology Directorate  
 Jet Propulsion Laboratory

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Nicholas White  
 Director, Science and Exploration Directorate  
 Goddard Space Flight Center

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 James Wells  
 Mission Manager  
 Earth System Science Pathfinder Program

\_\_\_\_\_  
 Date

\_\_\_\_\_  
 Eric Lindstrom  
 Program Scientist  
 Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
 Date



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\_\_\_\_\_  
Eric Ianson  
Program Executive  
Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
Date

\_\_\_\_\_  
Ken Ledbetter  
Chief Engineer  
Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
Date

\_\_\_\_\_  
Michael Freilich  
Director, Earth Science Division  
Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
Date

\_\_\_\_\_  
Mike Luther  
Deputy Associate Administrator for Programs  
Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
Date

\_\_\_\_\_  
Chuck Gay  
Deputy Associate Administrator  
Science Mission Directorate, NASA Headquarters

\_\_\_\_\_  
Date

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### J.3 AQUARIUS COMMITMENT BASELINE

The following section details the Aquarius Project commitments as proposed to Congress in the 2011 President's Budget Request.

#### Project Commitments

Project commitments include major mission architecture elements and the organization responsible for providing that element. The primary responsibility for ESSP is to enable successfully delivery of the JPL Aquarius instrument to CONAE.

Table J-1 summarizes Aquarius Project commitments.

**Table J-1: Aquarius Project Commitments**

| Project Element   | Provider | Description  | FY 2010 PB Request | FY 2011 PB Request |
|---|----------|--|--------------------|--------------------|
| Aquarius Instrument (integrated radiometer/scatterometer) | JPL      | L-band microwave radiometer at 1.413 GHz; scatterometer at 1.26 GHz; SSS measurements with root-mean-sq. random errors and systematic biases $\leq 0.2$ psu on 150 km sq. scales over ice-free oceans. | Same               | Same               |
| Spacecraft  | CONAE    | SAC-D  | Same               | Same               |
| Launch Vehicle  | Boeing   | Delta II   | Same               | Same               |
| Data Management   | GSFC     | N/A  | Same               | Same               |
| Operations  | CONAE    | Command and telemetry  | Same               | Same               |

#### Schedule Commitments

The Aquarius mission entered a Risk Mitigation Phase (RMP) in July 2002. Following the RMP, the Project was authorized to proceed to a formulation phase in December 2003. The Aquarius Project was authorized by the NASA SMD to proceed to development on October 12, 2005. In November 2007, the NASA Science Directorate Program Management Council (DPMC) approved a rebaseline of Aquarius, including a launch delay to May 2010. In December 2009, the NASA Science DPMC approved another rebaseline of Aquarius, including a launch delay manifesting the Aquarius/SAC-D mission for a January 2011 launch. The Aquarius schedule commitments are summarized in Table J-2 and Table J-3 for the second rebaseline. Table J-4 summarizes development cost through the second rebaseline.

**Table J-2: Aquarius Schedule Commitments**

| Milestone Name                                    | Confirmation Baseline | FY 2010 PB Request | FY 2011 PB Request |
|---|-----------------------|--------------------|--------------------|
| <i>Development</i>                                |                       |                    |                    |
| Project Confirmation Review                       | September 2005        | September 2005     | September 2005     |
| Project CDR                                       | August 2007           | July 2008          | July 2008          |
| Aquarius Instrument Pre-ship Review [FY 2008 APG] | May 2008              | May 2009           | May 2009           |
| Launch  | March 2009            | May 2010           | January 2011       |

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**Table J-3: Aquarius Development Cost and Schedule Summary**

| Project  | Base Year | Base Year Development Cost Estimate (\$M) | Current Year | Current Year Development Cost Estimate (\$M) | Cost Change (%) | Key Milestone    | Base Year Milestone Date | Current Year Milestone Date | Milestone Change (months) |
|----------|-----------|---|--------------|--|-----------------|------------------|--------------------------|-----------------------------|---------------------------|
| Aquarius | 2007      | 192.6                                     | 2010         | 222.6  | 16              | Launch Readiness | 07/2009                  | 01/2011                     | 18                        |

**Table J-4: Aquarius Development Cost Details**

| Element                   | Base Year Development Cost Estimate (\$M) | Current Year Development Cost Estimate (\$M) | Delta |
|---------------------------|---|--|-------|
| Total:                    | 192.6                                     | 222.6  | 30.0  |
| Payloads                  | 55.4                                      | 96.1   | 40.7  |
| Launch Vehicle/Services   | 78.9                                      | 79.4   | 0.5   |
| Ground Systems            | 5.5                                       | 5.5  | 0.0   |
| Science/Technology        | 10.9                                      | 11.8   | 0.9   |
| Other Direct Project Cost | 41.9                                      | 29.8   | -12.1 |

### Project Management

The Jet Propulsion Laboratory is responsible for project management. The Science DPMC is responsible for program oversight. The ESD Director is the responsible official. Table J-5 summarizes responsibilities for Aquarius Project elements.

**Table J-5: Aquarius Project Element Responsibilities**

| Project Element     | Project Management Responsibility | NASA Center Performers | Cost-Sharing Partners |
|---------------------|-----------------------------------|------------------------|-----------------------|
| Launch Vehicle      | KSC                               | KSC                    | None                  |
| Ground System       | JPL                               | GSFC                   | None                  |
| Aquarius Instrument | JPL                               | JPL                    | None                  |
| Spacecraft          | CONAE                             | None                   | CONAE                 |
| Radiometer          | JPL                               | GSFC                   | None                  |
| Data management     | GSFC                              | GSFC/JPL               | None                  |
| Mission operations  | CONAE                             | None                   | CONAE                 |

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## **Appendix K Orbiting Carbon Observatory-2 (OCO-2)**

### **K.1 OCO-2 DESCRIPTION**

The original Orbiting Carbon Observatory was launched on February 24, 2009, but was lost after the launch vehicle payload fairing failed to separate. Like its predecessor, OCO-2 was designed to return the space-based measurements needed to provide global estimates of atmosphere carbon dioxide (CO<sub>2</sub>) with the sensitivity, accuracy, and sampling density needed to quantify regional scale carbon sources and sinks and characterize their behavior over the annual cycle. For its two-year prime mission, OCO-2 is to fly in a Sun-synchronous orbit that provides near global coverage of the sunlit portion of the Earth with a 16-day repeat cycle. Its single instrument incorporates three high-resolution grating spectrometers that are designed to measure the near-infrared absorption of reflected sunlight in CO<sub>2</sub> and molecular oxygen (O<sub>2</sub>) absorption bands. OCO-2 will validate a space-based measurement approach and analysis concept that can be used for future systematic CO<sub>2</sub> monitoring projects. OCO-2 was approved to proceed into Phase C in September 2010. The Project Manager leads the JPL Project team and is responsible to NASA for scientific integrity and the management.

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## **K.2 OCO-2 LEVEL 1 REQUIREMENTS**

### **Appendix K - Earth System Science Pathfinder Program Plan**

# **Program-Level Requirements for the Orbiting Carbon Observatory – 2 Project**

**Version: 1.0**  
**Date: September 24, 2010**

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### Change Log

| Revision | Date      | Sections Changed | Author    |
|----------|-----------|------------------|-----------|
| 1.0      | 9/24/2010 | Initial Release  | E. Ianson |
|          |           |                  |           |
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## **1.0 SCOPE**

This appendix to the Earth System Science Pathfinder (ESSP) Program Plan identifies the mission, science and programmatic (funding and schedule) requirements imposed on the Jet Propulsion Laboratory (JPL) for the development and operation of the Orbiting Carbon Observatory – 2 (OCO-2) Project of the ESSP Program. Requirements begin in Section 4. Sections 1, 2 & 3 are intended to set the context for the requirements that follow.

This document serves as the basis for mission assessments conducted by NASA Headquarters during the development period and provides the baseline for the determination of the science mission success following the completion of the operational phase.

Program authority is delegated from the Associate Administrator for the Science Mission Directorate (AA/SMD) through the Earth Science Division within SMD to the ESSP Program Manager at Langley Research Center. Project management will be conducted at JPL. See Section 3.1.

JPL is responsible for scientific success, design, development, test, mission operations, and data verification tasks and shall coordinate the work of all contractors and science team members.

The NASA Earth Science Division will select the investigators that will compose the OCO-2 Science Team through a competitive process.

Changes to information and requirements contained in this document require approval by the Science Mission Directorate (SMD), NASA Headquarters by the officials that approved the original.

OCO-2 is based on the original OCO mission, which was developed under the NASA Earth System Science Pathfinder (ESSP) Program Office and launched from Vandenberg Air Force Base on February 24, 2009. Before spacecraft separation, a launch vehicle anomaly occurred that prevented the spacecraft from reaching injection orbit. The spacecraft was destroyed during re-entry and was unrecoverable.

## **2.0 SCIENCE DEFINITION**

### **2.1 BASELINE SCIENCE OBJECTIVES**

The ESSP OCO-2 Project will implement an exploratory science mission designed to collect the space-based measurements needed to quantify variations in the column averaged atmospheric carbon dioxide (CO<sub>2</sub>) dry air mole fraction, X<sub>CO<sub>2</sub></sub>, with the precision, resolution, and coverage needed to improve our understanding of surface CO<sub>2</sub> sources and sinks (fluxes) on regional scales



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( $\geq 1000$  km) and the processes controlling their variability over the seasonal cycle. This mission will also validate a space-based measurement approach and analysis concept that could be used for future systematic CO<sub>2</sub> monitoring missions.

## 2.2 SCIENCE INSTRUMENT SUMMARY DESCRIPTION

The OCO-2 instrument incorporates three near-infrared spectrometers designed to measure reflected sunlight in CO<sub>2</sub> and molecular oxygen (O<sub>2</sub>) absorption bands. Soundings, consisting of coincident CO<sub>2</sub> and O<sub>2</sub> spectra, are analyzed with a remote sensing retrieval algorithm to yield spatially-resolved estimates of X<sub>CO2</sub>. The spectrometer optical design, spectral range, and resolving power were selected to optimize measurement precision and minimize bias. Spectra collected at wavelengths near 1.61 microns are most sensitive to variations in the CO<sub>2</sub> concentration near the surface. Coincident measurements from the O<sub>2</sub> A-band and the CO<sub>2</sub> band near 2.06 microns minimize X<sub>CO2</sub> errors associated with pointing uncertainties and scattering by thin clouds and aerosols. The small ( $\leq 3$  km<sup>2</sup>) sounding footprint is expected to yield  $> 100$  cloud-free soundings on regional scales over  $> 80\%$  of range of latitudes on the sunlit hemisphere at monthly intervals.

The precision and bias of space-based X<sub>CO2</sub> retrievals can only be validated at locations where X<sub>CO2</sub> is well characterized by other methods. OCO-2 results will be validated through comparisons with X<sub>CO2</sub> retrievals from selected ground-based spectrometers in the Total Column Carbon Observing Network (TCCON). Retrievals from TCCON stations designated as OCO-2 "primary ground validation sites" have been validated against in situ CO<sub>2</sub> profiles collected during aircraft overflights of the station, using measurement techniques traceable to World Meteorological Organization standards for atmospheric CO<sub>2</sub> measurements. OCO-2 can acquire  $> 100$  soundings in the vicinity of a TCCON station in a single cloud-free overflight. At least once each season, space-based X<sub>CO2</sub> retrievals from cloud-free overflights of  $\geq 3$  of the primary ground validation sites will be compared with TCCON retrievals to validate the OCO-2 measurement precision and to identify global-scale systematic biases in its space-based X<sub>CO2</sub> product.

## 3.0 PROJECT DEFINITION

### 3.1 PROJECT ORGANIZATION & MANAGEMENT

The OCO-2 Project Manager shall report to NASA according to Figure 1.

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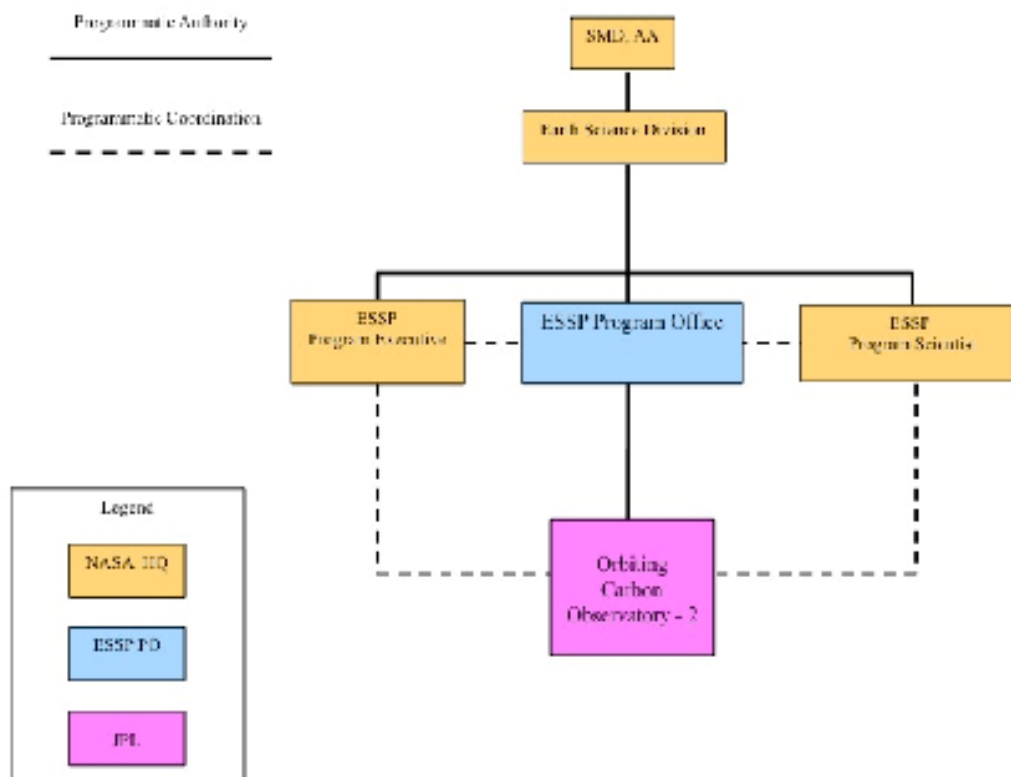


Figure 1. OCO-2 Lines of Authority and Coordination

The OCO-2 Project Manager has overall management responsibility for the success of the project. The OCO-2 Project Scientist has overall management responsibility for the science elements of the project. Specific assigned roles and responsibilities are:

- JPL is responsible for providing: the Project Scientist; project management; system engineering and mission design; safety and mission assurance; the instrument; spacecraft; mission operations and the associated mission operations ground data system; science data processing and delivery of calibrated/validated science data products to an archive for public distribution.
- NASA is responsible for providing a launch vehicle and launch services for OCO-2 and access to the SN (Space Network) for S-band uplink and downlink and Near Earth Network (NEN) for S-band uplink and downlink and X-band downlink compatible with the OCO-2 mission. A NASA-SMD-Earth Science Division-assigned Distributed Active Archive Center (DAAC) is responsible for public distribution of OCO-2 data and long-term science data archiving.

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### **3.2 PROJECT ACQUISITION STRATEGY**

JPL will implement an in-house development of the instrument, utilizing commercial vendors for parts and assemblies. However, the instrument cryocoolers will be obtained from the GOES-R (Geostationary Operational Environmental Satellite, R-Series) Program through an inter-agency transfer between NASA and NOAA (National Oceanic and Atmospheric Administration). Orbital Science Corporation (OSC) is contracted to provide the spacecraft development, integration, test, launch operations, and mission operations support. NASA's Launch Services Program at Kennedy Space Center will provide the launch vehicle. Sole source justifications will be implemented based on the past experience on OCO.

### **4.0 PROGRAMMATIC REQUIREMENTS**

The science objectives in Section 2.1 can be achieved by either the baseline or threshold science mission requirements listed herein, but the baseline mission provides substantially more value to NASA and the Earth Science Community.

#### **4.1 SCIENCE REQUIREMENTS**

##### **4.1.1 BASELINE SCIENCE REQUIREMENTS**

- a) Retrieve estimates of the column-averaged CO<sub>2</sub> dry air mole fraction ( $X_{CO_2}$ ) on regional scales ( $\geq 1000$  km) from space-based measurements of the absorption of reflected sunlight by atmospheric CO<sub>2</sub> and O<sub>2</sub>, collected in cloud-free scenes over  $\geq 80\%$  of range of latitudes on the sunlit hemisphere at monthly intervals for 2 years.
- b) Compare space-based and ground-based  $X_{CO_2}$  retrievals from soundings collected during overflights of  $\geq 3$  primary ground validation sites at least once each season to identify and correct global-scale systematic biases in the space-based  $X_{CO_2}$  product and to demonstrate a precision of  $\leq 0.3\%$  for collections of  $\geq 100$  cloud-free soundings.
- c) Record, validate, publish, and deliver science data records and calibrated geophysical data products to a NASA SMD-Earth Science Division-assigned DAAC for use by the scientific community.
- d) Validate a space-based measurement approach and analysis concept that could be used for future systematic CO<sub>2</sub> monitoring missions.

##### **4.1.2 THRESHOLD SCIENCE REQUIREMENTS**

- a) Retrieve estimates of the column-averaged CO<sub>2</sub> dry air mole fraction ( $X_{CO_2}$ ) on regional scales ( $\geq 1000$  km) from space-based measurements of the absorption of reflected sunlight by atmospheric CO<sub>2</sub> and O<sub>2</sub>, collected



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in cloud-free scenes over  $\geq 80\%$  of range of latitudes on the sunlit hemisphere at monthly intervals for  $\geq 1$  year.

- b) Compare space-based and ground-based  $X_{CO_2}$  retrievals from soundings collected during overflights of  $\geq 3$  primary ground validation sites at least once each season to identify and correct global-scale systematic biases in the space-based  $X_{CO_2}$  product and demonstrate a precision of  $\leq 0.5\%$  for collections of  $\geq 100$  cloud-free soundings.
- c) Record, validate, publish, and deliver science data records and calibrated geophysical data products to a NASA SMD-Earth Science Division-assigned DAAC for use by the scientific community.
- d) Validate a space-based measurement approach and analysis concept that could be used for future systematic  $CO_2$  monitoring missions.

#### **4.1.3 SCIENCE INSTRUMENT REQUIREMENTS**

- a) The space-based instrument shall be capable of acquiring coincident measurements of reflected sunlight in the  $CO_2$  bands centered at wavelengths near  $1.61$  and  $2.06 \mu m$  and in the  $O_2$  A-band centered near  $0.765 \mu m$ .
- b) The spectral range and resolving power of the space-based instrument shall be selected to resolve individual absorption lines from the underlying continuum throughout each  $CO_2$  and  $O_2$  band to retrieve estimates of  $X_{CO_2}$  that meet the Science Requirements (Section 4.1).
- c) The OCO-2 instrument shall be capable of acquiring  $CO_2$  and  $O_2$  soundings with a footprint size  $\leq 3 km^2$  at nadir to facilitate the acquisition of cloud-free scenes in at least  $10\%$  of the soundings collected over the sunlit hemisphere on monthly time scales.

#### **4.2 MISSION AND SPACECRAFT PERFORMANCE**

- a) The OCO-2 project shall be Category 2 per NPR 7120.5D, and the payload class shall be C per NPR 8705.4.
- b) The OCO-2 mission shall complete the In-Orbit Checkout (IOC) period within 90 days after launch, and then begin operations consistent with the science requirements in Section 4.1.1.
- c) The Observatory shall fly in a sun-synchronous low Earth orbit that provides access to  $\geq 90\%$  of the range of latitudes on the sunlit hemisphere at least once a month.

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- d) After IOC, the Observatory's orbit nodal crossing time shall be between 11AM and 2PM, and vary by less than 15 minutes during the science mission as defined in Section 4.2(e).
- e) The OCO-2 mission lifetime is 2 years baseline (1 year threshold) following completion of IOC.

#### **4.3 LAUNCH REQUIREMENTS**

- a) The Observatory shall be launched on an expendable launch vehicle of Risk Category 2 or 3, per NPD 8610.7C with a payload isolation damping system, if needed.
- b) The OCO-2 project shall target a Launch Readiness Date in February 2013.

#### **4.4 GROUND SYSTEM REQUIREMENTS**

The OCO-2 project shall develop a ground system to meet the performance requirements in section 4.1 and the reprocessing and data latency requirements in section 4.5.

#### **4.5 MISSION DATA REQUIREMENTS**

##### **4.5.1 SCIENCE DATA MANAGEMENT**

- a) The OCO-2 Project shall produce the standard science data products listed in Table 1.
- b) All standard data products listed in Table 1 shall be delivered, in accordance with the NASA Earth Science Data and Information Policy specified in the 2006 Earth Science Reference Handbook (NP-2006-5-768-GSFC), to a NASA SMD Earth Science Division-assigned DAAC. Public release of this data shall conform to the NASA Earth Science Data and Information Policy, U.S. Law, and the NASA/CalTech prime contract (NAS7-03001).
- c) Science algorithms used to generate the standard data products listed in Table 1 shall be documented in Algorithm Theoretical Basis Documents (ATBDs).

##### **4.5.1.1 SCIENCE DATA REQUIREMENTS**

- a) OCO-2's Level 1 and Level 2 science data product formats shall conform to the Hierarchical Data Format (HDF5) standard.
- b) The metadata for the OCO-2 standard data products listed in Table 1 shall

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conform to the Earth Observing System (EOS) Clearinghouse (ECHO) Science Metadata Model.

- c) The OCO-2 Project shall coordinate the release of product versions with the NASA SMD-Earth Science Division-assigned DAAC.
- d) The OCO-2 Project shall deliver reprocessed data products which meet the science requirements in Section 4.1 within 6 months after completion of the science mission as specified in Paragraph 4.2.e.
- e)  $X_{CO_2}$  products mapped on a uniform spatial grid shall be produced by the OCO-2 Project.

**Table 1. OCO-2 Data Products**

| Data Product | Description                              | Initial Availability to NASA DAAC                  | Median Latency in Product Availability to NASA DAAC after Initial Delivery | NASA DAAC Location |
|--------------|--|--|--|--------------------|
| Level 0      | Raw collected telemetry                  | Within 24 hours of receipt from EDOS*              | Within 24 hours of receipt from EDOS*                                      | GSFC               |
| Level 1      | Calibrated Geolocated Spectral Radiances | 3 months after IOC**                               | 3 weeks**  | GSFC               |
| Level 2      | $X_{CO_2}$                               | 3 months after Level 1 data products are available | 6 weeks**  | GSFC               |

\* EDOS: (Earth Observing System) Data and Operations System

\*\*Delivery latency after ground receipt

#### **4.5.2 APPLIED SCIENCE DATA REQUIREMENTS**

Beginning in Phase C, the OCO-2 Project shall participate in an OCO-2 data product application workshop annually. The workshop will share information on OCO-2 science data applications and define potential applications that can be supported with existing OCO-2 data requirements. Results of the workshop will be provided to the OCO-2 science team and at other OCO-2 workshops and meetings.

#### **4.6 MISSION SUCCESS CRITERIA**



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- a) Launch into a sun-synchronous orbit that provides near global access at monthly intervals.
- b) Collect global space-based measurements of atmospheric carbon dioxide (CO<sub>2</sub>) with the precision, resolution, and coverage needed to improve understanding of CO<sub>2</sub> sources and sinks and quantify their variability over an annual cycle (as specified in section 4.1.2).
- c) Record, validate, publish, and deliver science data records and calibrated geophysical data products to a NASA SMD-Earth Science Division-assigned DAAC for use by the scientific community.
- d) Validate a space-based measurement approach and analysis concept for future systematic CO<sub>2</sub> monitoring missions.

## **5.0 NASA MISSION COST REQUIREMENT**

### **5.1 Cost**

The OCO-2 life cycle cost (LCC) shall not exceed \$325.8M. The LCC includes the cost for the formulation, implementation, launch, operations, calibration, validation, science data analysis costs to generate the products in Table 1, and \$10M (a not-to-exceed figure) for the two cryocoolers obtained from the NOAA GOES-R Program.

### **5.2 Cost MANAGEMENT AND SCOPE REDUCTION**

Provided that Program Level Requirements are preserved, and that due consideration has been given to the use of budgeted contingency and planned schedule contingency, the OCO-2 project shall pursue scope reduction and risk management as a means to control cost. The Project Plan shall include potential scope reductions and the time frame in which they could be implemented. If other methods of cost containment are not practical, the reductions identified in the Project Plan may be exercised.

Scope reductions from baseline science requirements (Section 4.1.1) to threshold science requirements (Section 4.1.2) or potential scope reductions affecting these Program Requirements shall be agreed to by the officials represented on the approval page of document.

## **6.0 MULTI-MISSION NASA FACILITIES**

- a) The NASA Near Earth Network (NEN) shall be made available by NASA for S-band uplink and downlink and X-band downlink compatible with the OCO-2 Mission.
- b) The SN, also known as the NASA Tracking and Data Relay Satellite System (TDRSS) shall be made available by NASA for rapid

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communications between the spacecraft and ground during the IOC, orbit correction maneuvers, and emergencies.

## **7.0 EXTERNAL AGREEMENTS**

- a) The OCO-2 mission shall include no flight hardware or flight software contributions from organizations outside of NASA, precluding the need for external agreements for flight hardware or software contributions.
- b) The OCO-2 Project shall reimburse NOAA (National Oceanic and Atmospheric Administration) for the two GOES-R (Geostationary Operational Environmental Satellite, Series R) Program cryocoolers per the countersigned inter-agency transfer MOA (Memorandum Of Agreement).
- c) The scope of the contributions from the international or interagency partners on the OCO-2 Science Team, validation activities, or data sharing shall be described in formal agreements between NASA and these organizations.

## **8.0 PUBLIC OUTREACH AND EDUCATION**

The OCO-2 project shall develop and execute an Education and Public Outreach Plan.

## **9.0 SPECIAL INDEPENDENT EVALUATION**

No special independent evaluation is required for the OCO-2 Project.

## **10.0 WAIVERS**

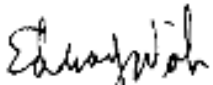
The OCO-2 Project was granted Agency approval to complete a tailored formulation phase that reduced that number of KDP gates, gate product versions, and technical reviews during this period.




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## 11.0 REQUIRED APPROVALS AND CONCURRENCES


### APPROVALS

  
 \_\_\_\_\_  
 Edward Weiler  
 Associate Administrator, Science Mission Directorate  
 NASA Headquarters

9-24-10  
 \_\_\_\_\_  
 Date

  
 \_\_\_\_\_  
 Charles Elachi  
 Director, Jet Propulsion Laboratory

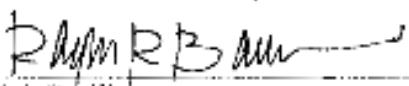
9-2-2010  
 \_\_\_\_\_  
 Date

  
 \_\_\_\_\_  
 Greg Stover  
 Program Manager (Acting), Earth System Science Pathfinder Program  
 NASA Langley Research Center


26 Aug 2010  
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 Date

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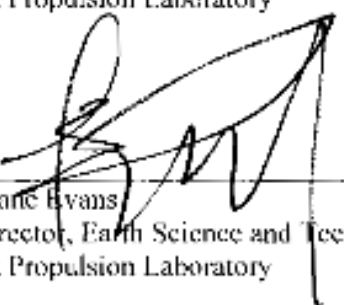
## CONCURRENCES

  
 Ralph Basilio  
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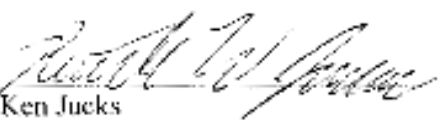
24 AUG 2010  
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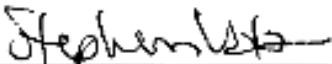
  
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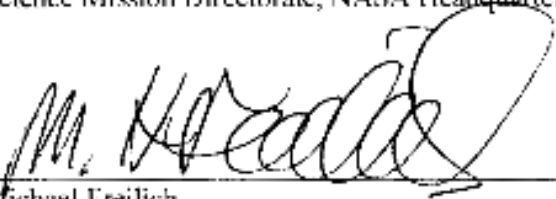
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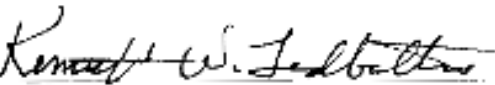
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### K.3 OCO-2 COMMITMENT BASELINE

#### NASA SMD Program Management Council Project KDP Decision Agreement

**Summary:** The Science Mission Directorate Program Management Council met on September 24, 2010 and evaluated the Orbiting Carbon Observatory – 2 (OCO-2) project's Key Decision Point C of the life cycle as defined in NASA Procedural Requirement 7120.5: Space Flight Program and Project Management Requirements. The DPMC determined that the project is ready to proceed to Phase C.

**Decision:** Based on this review and the project readiness documents, the Decision Authority for the OCO-2 project grants approval for the project's Phase C with the content, schedule, and cost profile specified in the attached summary and reflected in Table 1, below. The OCO-2 project has significantly leveraged the experience from OCO and has been funded appropriately (both total LCC and phasing) to put the project in an excellent position to succeed. This decision includes the actions specified below.

**Table 1: KDP-C Cost and Schedule Baseline Commitments**

|  | Management (Internal to Project) <sup>1</sup> | Agency Baseline Commitment (Reported External to NASA) <sup>2</sup> |
|--|---|---|
| Cost – LCC (Phases A through F) Commitment   | \$325.9M                                      | \$349.9M  |
| Cost – Development (Phases C & D) Commitment | \$227.0M                                      | \$249.0M  |
| Schedule (LRD)                               | February 2013                                 | February 2013   |
| Years/Months of Operations                   | 24 months                                     | 24 months   |
| Joint Confidence Level (Cost and Schedule)   | >50%  | >70%  |

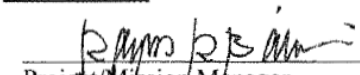


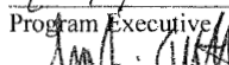
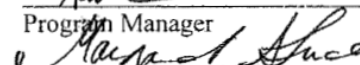
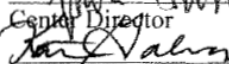
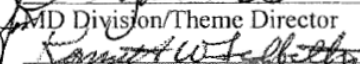
**Notes:**

- The JCL was performed for Phases C & D, excluding project managed Unallocated Future Expenses (UFE), JPL fees, launch services, and low-level fixed cost activities at GSFC (Exploration and Space Communications, EOS Data and Operations System, Flight Dynamics Facility, and NASA Integrated Services Network)
- The Development Commitment includes all activities for Phases C & D
- Months of operation is after the In-Orbit Checkout (IOC) Period

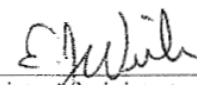
<sup>1</sup>Includes the UFE and schedule margin to be managed by the project, project labor, and project CoF.

<sup>2</sup>Includes all project UFE and schedule margin, including UFE and margin to be managed above the project. Also includes legacy indirect costs.

#### Concurrence

|   |             |  |         |
|---|-------------|--|---------|
|  | 9/24/2010   |  | 9/24/10 |
| Project/Mission Manager   | Date        | Program Executive  | Date    |
|  | 24 Sep 2010 |  | 9-24-10 |
| Program Manager   | Date        | Center Director  | Date    |
|  | 9/24/10     |  | 9/24/10 |
| MD Division/Theme Director  | Date        | Chief Financial Officer designee   | Date    |
|  | 9/24/10     |  |         |
| Chief Engineer designee   | Date        |  |         |

#### Approval

 9-24-10

MD Associate Administrator Date

During formulation, the Project Manager agrees that the ensuing phase can be completed within the Management commitment. During implementation, the Project Manager agrees that the project lifecycle can be completed within the

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Management commitment; the Program Manager and Mission Directorate agree that the Project can be completed within the External (External to NASA) Commitment as listed in the right column in the table above.

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## **Appendix L Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS)**

### **L.1 AIRMOSS DESCRIPTION**

North American ecosystems are critical components of the global carbon cycle, exchanging large amounts of carbon dioxide and other gases with the atmosphere. Root-zone soil measurements can be used to better understand these carbon fluxes and their associated uncertainties on a continental scale. The goal of the Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) investigation is to provide high-resolution observations of root-zone soil moisture over regions representative of the major North American climatic habitats (biomes), quantify the impact of variations in soil moisture on the estimation of regional carbon fluxes, and extrapolate the reduced-uncertainty estimates of regional carbon fluxes to the continental scale of North America.

AirMOSS will use an airborne ultra-high frequency synthetic aperture radar to penetrate through substantial vegetation canopies and soil to depths down to approximately 1.2 meters. For AirMOSS, NASA's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) will be flown on a Gulfstream-III aircraft. Extensive ground, tower, and aircraft in-situ measurements will validate root-zone soil measurements and carbon flux model estimates. The surveys will provide measurements at 100 meter spatial resolution and at sub-weekly, seasonal, and annual time scales.

AirMOSS responds directly to challenges set down by the NASA Carbon Cycle Science and the North American Carbon Program. Additionally, AirMOSS data provide a direct means for validating root-zone soil measurement algorithms from the Soil Moisture Active & Passive (SMAP) mission and assessing the impact of fine-scale heterogeneities in its coarse-resolution products.

The UAVSAR instrument operating for the first time at UHF band will provide measurements of root zone soil moisture, net ecosystem exchange, CO<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>O, soil moisture, temperature and water potential profile. The tower sites will use Fluxnet sensors and provide soil moisture, temperature, vegetation characteristics and water and carbon flux. The in-situ aircraft instrument will be the Piccaro spectrometer, which will measure CO<sub>2</sub>, CH<sub>4</sub>, and H<sub>2</sub>O. Tower and aircraft instruments have been used in numerous missions over several years.

The PI is from the University of Michigan, Ann Arbor, and JPL is responsible for project management.

Cost: \$25.9M over five years (2010-2015)

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## **Appendix M Airborne Tropical Tropopause Experiment (ATTREX)**

### **M.1 ATTREX DESCRIPTION**

Stratospheric water vapor has large impacts on the Earth's climate and energy budget. Future changes in stratospheric humidity and ozone concentration in response to changing climate are significant climate feedbacks. While the tropospheric water vapor climate feedback is well represented in global models, predictions of future changes in stratospheric humidity are highly uncertain because of gaps in our understanding of physical processes occurring in the region of the atmosphere that controls the composition of the stratosphere, the Tropical Tropopause Layer. Uncertainties in the Tropical Tropopause Layer region's chemical composition also limit our ability to predict future changes in stratospheric ozone. By improving our understanding of the processes that control how much water vapor gets into this region from lower in the atmosphere, the ATTREX investigation will directly address these uncertainties in our knowledge of the climate system.

The proposed instruments will provide measurements to trace the movement of reactive halogen-containing compounds and other important chemical species, the size and shape of cirrus cloud particles, water vapor, and winds in three dimensions through the Tropical Tropopause Layer. In particular, bromine-containing gases will be measured to improve our understanding of stratospheric ozone. ATTREX will consist of four NASA Global Hawk Uninhabited Aerial System (UAS) campaigns deployed from NASA's Dryden Flight Research Center (DFRC) in Edwards, CA, Guam, Hawaii, and Darwin, Australia taking place in Boreal summer, winter, fall, and summer, respectively.

The proposed investigation fills several significant gaps in atmospheric science identified in the 2007 Decadal Survey involving climate change, stratospheric ozone, and stratosphere-troposphere exchange.

ATTREX uses a Cloud Physics LIDAR (CPL) to provide aerosol/cloud backscatter. The ATTREX instrument is a copy of one which first deployed in 2000 and is currently awaiting its first flight. An absorption photometer measures ozone and has flown on several WB-57 missions. An Advanced Whole Air Sampler (AWAS) measures tracers with varying lifetimes and will need to be modified for this series of missions. A UAS Chromatograph for Atmospheric Trace Species (UCATS) measures O<sub>3</sub>, CH<sub>4</sub>, N<sub>2</sub>O, SF<sub>6</sub>, H<sub>2</sub>O, and CO and has flown on multiple missions. A Picarro Cavity Ring-Down Spectrometer (PCRS) will measure CO and CO<sub>2</sub>. The hardware flew as a prototype in 2009 and is considered to be TRL 7 and 8. A UAS Laser Hygrometer (ULH) and a Diode Laser Hygrometer (DLH) measure H<sub>2</sub>O. The DLH has flown for 15 years while the ULH predecessor flew in 2007. Hawkeye measures ice crystal properties. The Solar Spectral Flux Radiometer (SSFR) measures radiation fluxes and has flown on many missions. The Meteorological Measurement System (MMS) measures temperature and winds and has flown for two decades. The Microwave Temperature Profiler (MTP) measures temperature profile and has flown on five airborne platforms, but has not yet flown on Global

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Hawk. The Differential Optical Absorption Spectrometer (DOAS) measures  $\text{BrO}_3^-$ ,  $\text{NO}_2$ ,  $\text{OClO}$ , and IO and is a new instrument.

The PI is from Ames Research Center (ARC), and ARC is responsible for project management.

Cost: \$29.3M over five years (2010-2015)



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## **Appendix N Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)**

### **N.1 CARVE DESCRIPTION**

The carbon budget of Arctic ecosystems is not known with confidence since fundamental elements of the complex Arctic biological-climatologic-hydrologic system are poorly quantified. CARVE will collect detailed measurements of important greenhouse gases on local to regional scales in the Alaskan Arctic and demonstrate new remote sensing and improved modeling capabilities to quantify Arctic carbon fluxes and carbon cycle-climate processes. Ultimately, CARVE will provide an integrated set of data that will provide unprecedented experimental insights into Arctic carbon cycling.

CARVE will use the Arctic-proven De Havilland DHC-6 Twin Otter aircraft to fly an innovative airborne remote sensing payload. It includes an L-band radiometer/radar and a nadir-viewing spectrometer to deliver the first simultaneous measurements of surface parameters that control gas emissions (i.e., soil moisture, freeze/thaw state, surface temperature) and total atmospheric columns of carbon dioxide, methane, and carbon monoxide. The aircraft payload also includes a gas analyzer that links greenhouse gas measurements directly to World Meteorological Organization standards. Deployments will occur during the spring, summer, and early fall when Arctic carbon fluxes are large and change rapidly. Further, at these times, the sensitivities of ecosystems to external forces such as fire and anomalous variability of temperature and precipitation are maximized. Continuous ground-based measurements provide temporal and regional context as well as calibration for CARVE airborne measurements.

CARVE science fills a critical gap in Earth Science knowledge and satisfies high priority objectives across NASA's Carbon Cycle & Ecosystems, Atmospheric Composition, and Climate Variability & Change focus areas as well as the Air Quality and Ecosystems elements of the Applied Sciences program. CARVE complements and enhances the science return from current NASA and non-NASA satellite sensors.

A Passive Active L-band System (PALS) provides measurements of soil moisture, inundation state, surface freeze-thaw state and surface temperature and has been flying since 1998. A Tsukuba airborne Fourier Transform Spectrometer (FTS) measures the total column of CO<sub>2</sub>, CH<sub>4</sub> and CO. An In situ Gas Analyzer (ISGA) provides measurements of CO<sub>2</sub>, CH<sub>4</sub> and CO and was demonstrated in the Balanço Atmosférico Regional de Carbono na Amazônia (BARCA) campaign. A Programmable Flash Pack (PFP) provides CO<sub>2</sub>, CH<sub>4</sub> and CO. Both the ISGA and the PFP are COTS instrumentation.

The PI is from JPL, and JPL is responsible for project management.

Cost: \$27.9M over five years (2010-2015)

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## **N.2 CARVE PROGRAM LEVEL REQUIREMENTS ANNEX**

### **Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) Investigation**

A NASA Earth Ventures (EV-1) Mission

## **Program-Level Requirements and Investigation Success Criteria**

Version: 1  
Date: Friday, January 14, 2011

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**ESSP PROGRAM PLAN**

**CARVE Program-LEVEL REQUIREMENTS**  
**& INVESTIGATION SUCCESS CRITERIA**

## **Change Log**

| <b>Revision</b> | <b>Date</b> | <b>Sections Changed</b> | <b>Author</b> |
|-----------------|-------------|-------------------------|---------------|
| Version 1       | 1/14/2011   | Initial Release         | M. Avery      |

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## CARVE Program-LEVEL REQUIREMENTS & INVESTIGATION SUCCESS CRITERIA

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### **ESSP PROGRAM PLAN**

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### **& INVESTIGATION SUCCESS CRITERIA**

## **APPENDIX N.2 TO THE EARTH SYSTEM SCIENCE PATHFINDER PROGRAM PLAN**

### **PROGRAM-LEVEL REQUIREMENTS ON THE CARBON IN ARCTIC RESERVOIRS VULNERABILITY EXPERIMENT INVESTIGATION**

## **1.0 SCOPE**

This appendix to the ESSP Program Plan identifies the investigation, science and programmatic (funding and schedule) requirements imposed on the Principal Investigator and the Jet Propulsion Laboratory, California Institute of Technology (JPL) for the development and operation of the Earth Venture-1 (EV-1) Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) Investigation of the ESSP Program. Requirements begin in Section 4. Sections 1, 2 & 3 are intended to set the context for the requirements that follow.

This document serves as the basis for investigation assessments conducted by NASA Headquarters during the development period and provides the baseline for the determination of the science mission success following the completion of the operational phase.

Program authority is delegated from the Associate Administrator for the Science Mission Directorate (AA/SMD) through the Earth Science Division (ESD) within SMD to the ESSP Program Manager at NASA Langley Research Center. Investigation management will be conducted at the JPL as described in Section 3.1.

The Principal Investigator (PI) at the JPL is responsible for the scientific success of the CARVE Investigation, including the design, development, integration and testing, investigation operations, and data verification tasks, and shall coordinate the work of all contractors and co-investigators.

Changes to information and requirements contained in this document require approval by the Earth Science Division (ESD), NASA Headquarters, and by the officials that approved the original.

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## APPENDIX N.2

### ESSP PROGRAM PLAN

### CARVE Program-LEVEL REQUIREMENTS & INVESTIGATION SUCCESS CRITERIA

## 2.0 SCIENCE DEFINITION

### 2.1 BASELINE SCIENCE OBJECTIVES

The carbon balance of ecosystems in the Alaskan Arctic is not known with confidence since fundamental elements of the complex biological-climatologic-hydrologic system are poorly quantified. No current or planned space-based or sub-orbital system provides *coincident* measurements of surface controls and atmospheric concentrations required to quantify these processes. CARVE's science objectives are to fill this critical gap in science knowledge by:

- (1) Directly testing hypotheses attributing the mobilization of vulnerable Alaskan Arctic carbon reservoirs to climate warming;
- (2) Delivering the first direct measurements and detailed maps of CO<sub>2</sub> and CH<sub>4</sub> sources on regional scales in the critical Alaskan Arctic ecozone; and
- (3) Demonstrating new remote sensing and modeling capabilities to quantify feedbacks between carbon fluxes and carbon cycle-climate processes in the Alaskan Arctic region.

CARVE measurements and integrated science data will provide unprecedented experimental insights into Alaskan Arctic carbon cycling and its response to climate change. The quantified correlations between surface controls and atmospheric composition determined from CARVE data will provide powerful new tools for understanding current Alaskan ecosystems as well as their role within the pan-Arctic region and retrospective analyses that extend this understanding over the entire length of various satellite sensor data records. The CARVE investigation augments projects across NASA Earth Science research and applications programs and establishes the foundation for a community-wide Arctic-based follow-on to the Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA). CARVE will also inform the development of retrieval algorithms and validation strategies for future satellite observations.

### 2.2 SCIENCE INSTRUMENT SUMMARY DESCRIPTION

#### 2.2.1 INVESTIGATION OVERVIEW

The CARVE Investigation is designed to reconcile Alaskan Arctic carbon fluxes estimated from atmospheric concentrations of CO<sub>2</sub> and CH<sub>4</sub> measured with remote sensing and *in situ* techniques (top-down approach) with carbon fluxes estimated from coincident remote sensing measurements of surface state controls (bottom-up approach). The CARVE Science Investigation entails intensive seasonal deployments in Alaska during the spring thaw, summer draw-down, and fall refreeze of the Arctic growing season over multiple years. CARVE flight plans sample multiple permafrost domains and ecosystems, and deliver



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detailed measurements over ground-based measurement sites, fires, and burn-recovery chronosequences. Large deployment schedule margins provide resiliency against poor weather and the flexibility to exploit unusual findings or geophysical conditions.

#### **2.2.2 INSTRUMENT PAYLOAD AND PLATFORM**

The CARVE investigation is implemented with a suite of three instruments: (1) JPL's Passive Active L-band System (PALS); (2) a Fourier transform spectrometer (FTS) with optical filters optimized to meet CARVE science requirements; and (3) an *In Situ* Gas Analyzer Suite (ISGAS) for continuous CO<sub>2</sub>, CH<sub>4</sub> and CO measurements and whole air sampling.

The investigation platform is the De Havilland DHC-6 *Twin Otter*, a highly reliable, Arctic-proven aircraft. The Twin Otter has the mass, volume, and power capacities to accommodate the payload with robust margins, and the flight performance required to meet the CARVE science objectives.

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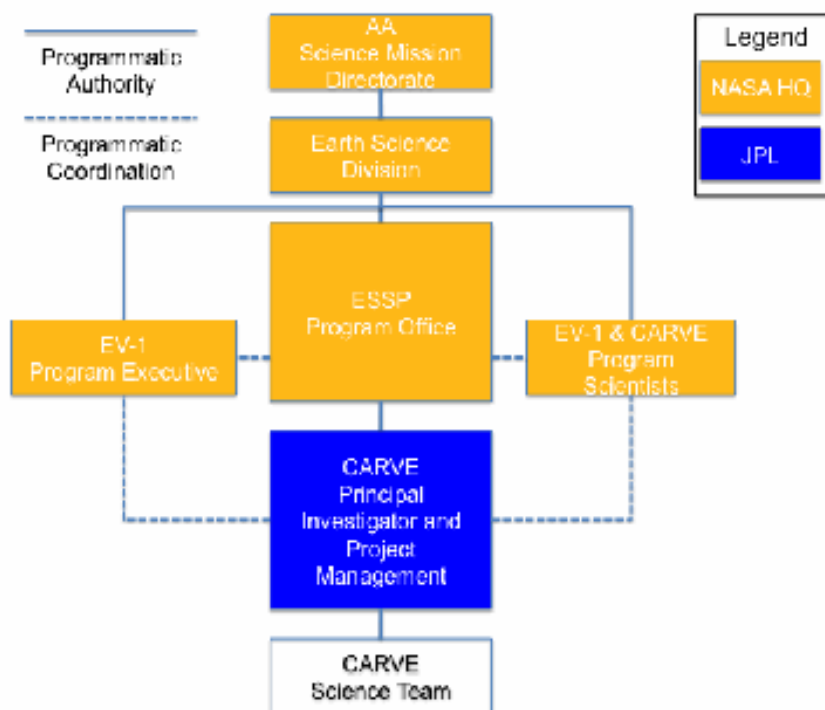
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**& INVESTIGATION SUCCESS CRITERIA**

### 3.0 INVESTIGATION DEFINITION

#### 3.1 INVESTIGATION ORGANIZATION & MANAGEMENT

CARVE is a Principal Investigator (PI)-led investigation. The PI is responsible for investigation success. He delegates authority for day-to-day implementation of the investigation to the Project Manager (PM). Both the PI and the PM reside at the JPL. CARVE's management structure and lines of reporting are shown in Figure 1.



**Figure 1. CARVE Lines of Authority and Coordination**

Specific assigned roles and responsibilities are:

- NASA ESD is responsible for providing: the Program Scientists; the Program Executive; program management through the ESSP Program Office; the storage and distribution of CARVE data and data products after the Investigation Closeout; coordination with relevant NASA projects and programs; sponsoring Venture Class data product applications workshops; sponsoring EV-1 Education and Public Outreach



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## CARVE Program-LEVEL REQUIREMENTS & INVESTIGATION SUCCESS CRITERIA

- JPL is responsible for providing: the Project Manager; project management; system engineering and mission design; safety and mission assurance; the payload; the payload integration and test; mission operations and the associated mission operations ground data system; science data processing and delivery of calibrated/validated science data products for public distribution.
- NASA Ames is responsible for NASA flight safety and mission assurance requirements, airworthiness and flight readiness reviews, per NPR 7900.3B and/or NPD 7900.4C.

### 3.2 INVESTIGATION ACQUISITION STRATEGY

*Science Instrument Payload:* PALS is an existing JPL institutional instrument. The FTS, continuous *in situ* gas analyzer, and whole air sampling systems will be acquired as commercial off-the-shelf (COTS) purchases from established vendors.

*Platform:* NASA WFF will lease the investigation platform, a DHC-6 Twin Otter, to accomplish the investigation science objectives.

*Science Team:* The Investigation will execute subcontracts with the home institutions of all co-investigators through existing JPL business infrastructure.

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### ESSP PROGRAM PLAN

## CARVE Program-LEVEL REQUIREMENTS

### & INVESTIGATION SUCCESS CRITERIA

## 4.0 PROGRAMMATIC REQUIREMENTS

The science objectives in Section 2.1 are achieved by either the baseline or threshold science investigation requirements listed herein, but the baseline investigation provides substantially more value to NASA and the Earth Science Community.

### 4.1 SCIENCE REQUIREMENTS

#### 4.1.1 BASELINE SCIENCE REQUIREMENTS

The CARVE Investigation shall

- a. Conduct at least three (3) aircraft measurement campaigns in the Alaskan Arctic (55N to 72N, 140W to 170W) per year, one each during the spring thaw, summer draw-down, and autumn refreeze periods in each of at least three (3) years
- b. Acquire aircraft measurements over multiple permafrost domains, ecosystems, and disturbance recovery zones during each aircraft campaign
- c. Acquire coincident remote sensing measurements of critical surface control variables (freeze/thaw state, inundation state, soil moisture, surface temperature) along with remote sensing and continuous *in situ* measurements of atmospheric CO<sub>2</sub>, CH<sub>4</sub> and CO concentrations during each aircraft campaign, meeting the measurement characteristics in Section 4.2
- d. Acquire science data as described in b) and c) during at least 500 aircraft flight hours
- e. Estimate CO<sub>2</sub> and CH<sub>4</sub> fluxes and associated uncertainty with horizontal resolution of at least 100 km for the Alaskan Arctic during the Investigation science operations period using CARVE measurements with the measurement characteristics defined in Section 4.2
- f. Record, validate, publish, and deliver science data and calibrated geophysical data products to the scientific community

#### 4.1.2 THRESHOLD SCIENCE REQUIREMENTS

The CARVE Investigation Shall

- a. Conduct at least two (2) aircraft measurement campaigns in the Alaskan Arctic (55N to 72N, 140W to 170W) per year between the spring thaw and the autumn refreeze in each of at least two (2) years

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### ESSP PROGRAM PLAN

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- b. Acquire aircraft measurements over multiple permafrost domains, ecosystems, and disturbance recovery zones during each aircraft campaign
- c. Acquire coincident remote sensing measurements of critical surface control variables (freeze/thaw state, inundation state, soil moisture) with continuous *in situ* measurements of atmospheric CO<sub>2</sub> and CH<sub>4</sub> concentrations during each aircraft campaign, meeting the measurement characteristics in Section 4.2
- d. Acquire science data as described in b) and c) during at least 320 aircraft flight hours
- e. Estimate CO<sub>2</sub> and CH<sub>4</sub> fluxes and associated uncertainty with horizontal resolution of at least 500 km for the Alaskan Arctic during the Investigation science operations period using CARVE measurements with the measurement characteristics defined in Section 4.2
- f. Record, validate, publish, and deliver science data and calibrated geophysical data products to the scientific community

#### 4.1.3 SURFACE MEASUREMENT REQUIREMENTS

- a) The CARVE network shall include ground sites located within multiple permafrost domains, ecosystems, and disturbance recovery zones, as appropriate to meet the science objectives.
- b) The CARVE network shall include ground sites with measurements of carbon fluxes and energy balance.
- c) The CARVE network shall include ground sites with carbon isotope measurements of CO<sub>2</sub>Δ<sup>14</sup>C and CH<sub>4</sub>Δ<sup>14</sup>C.

#### 4.2 SCIENCE INSTRUMENT REQUIREMENTS

- a) The aircraft science instrument payload shall deliver remote sensing measurements of soil freeze/thaw state, inundation state, soil moisture, and soil surface temperature with the following precisions:

| Measurement                   | Single Measurement Confidence |
|-------------------------------|-------------------------------|
| Soil moisture                 | ±10%                          |
| Inundation state, error rate  | <30%                          |
| Freeze/Thaw state, error rate | <30%                          |
| Soil surface temperature      | 3°C, 1σ                       |

- b) The aircraft science instrument payload shall deliver remote sensing

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measurements of CO<sub>2</sub>, CH<sub>4</sub> and CO with the following precisions:

| Measurement     | Remote Sensing Measurements             |
|-----------------|---|
|                 | Precision (Total Column, 5 sec avg, 1σ) |
| CO <sub>2</sub> | 3 ppm                                   |
| CH <sub>4</sub> | 25 ppb                                  |
| CO              | 30 ppb                                  |

- c) The aircraft science instrument payload shall deliver continuous *in situ* measurements of CO<sub>2</sub>, CH<sub>4</sub> and CO with the following precisions:

| Measurement     | Continuous In Situ Measurements |
|-----------------|---------------------------------|
|                 | Precision (5 sec avg, 1σ)       |
| CO <sub>2</sub> | 1.0 ppm                         |
| CH <sub>4</sub> | 5 ppb                           |
| CO              | 20 ppb                          |

- d) The aircraft science instrument payload shall collect whole air samples for post-flight chemical analysis which include isotopic species detection with the following precisions:

| Measurement                       | Precision (1σ) |
|-----------------------------------|----------------|
| CO <sub>2</sub> δ <sup>13</sup> C | 0.3‰           |
| CO <sub>2</sub> δ <sup>18</sup> O | 0.5‰           |
| CO <sub>2</sub> Δ <sup>14</sup> C | 10‰            |
| CH <sub>4</sub> δ <sup>13</sup> C | 0.5‰           |
| CH <sub>4</sub> δD                | 3‰             |

- e) The ground site carbon isotope measurements shall have the following precisions:

| Measurement                       | Precision (1σ) |
|-----------------------------------|----------------|
| CO <sub>2</sub> Δ <sup>14</sup> C | 10‰            |
| CH <sub>4</sub> Δ <sup>14</sup> C | 10‰            |

## 4.3 AIRCRAFT PERFORMANCE AND SAMPLING REQUIREMENTS

- The Investigation aircraft shall fly in Arctic conditions.
- The science instrument payload and crew required to deliver the airborne measurements defined in Section 4.2 shall be carried aboard a single aircraft.
- The Investigation aircraft shall fly in controlled and uncontrolled airspace.



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- d) The investigation aircraft shall fly at cruising speeds between 80 and 120 knots to enable the remote sensing measurements defined in Section 4.2.

## 4.4 GROUND SYSTEM REQUIREMENTS

- a) The ground system shall ingest, and store meteorological data for flight planning during the campaign periods.
- b) The ground system shall ingest and geolocate all data from the science payload.
- c) The ground system shall process raw data to provide the standard data products listed in Table 1.

## 4.5 INVESTIGATION DATA REQUIREMENTS

### 4.5.1 SCIENCE DATA MANAGEMENT

- a) The CARVE Investigation shall produce the standard science data products listed in Table 1.
- b) The CARVE Investigation standard science data products and associated metadata shall be made publicly available with the latencies given in Table 1. There shall be no period of exclusive access.
- c) Science algorithms and calibration procedures used to generate the standard data products listed in Table 1 shall be described in documents that are accessible to users after the latencies given in Table 1.
- d) By the Investigation Closeout, the CARVE Investigation shall deliver all standard data products, along with the scientific algorithm software, coefficients, ancillary data used to generate these products, and the algorithm and calibration documentation to the Oak Ridge National Laboratory Distributed Active Archive Center for Biogeochemical Dynamics.
- e) All terms and conditions of the transfer of data products and associated information to the Oak Ridge National Laboratory Distributed Active Archive Center for Biogeochemical Dynamics shall be documented in a Data Management Plan that has been approved by the Earth Science Data and Information System Project.

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**Table 1. CARVE Data Products**

| Product | Description  | Latency<br>Not to Exceed |
|---------|--|--------------------------|
| Level 1 | Calibrated, geolocated L-band emissivities and back-scatter signals  | 9 months                 |
| Level 1 | Calibrated, geolocated near infrared spectral radiances  | 9 months                 |
| Level 2 | Soil moisture, soil freeze/thaw state, inundation state and soil surface temperature   | 12 months                |
| Level 2 | Column CO <sub>2</sub> , CH <sub>4</sub> and CO  | 12 months                |
| Level 2 | Continuous <i>in situ</i> CO <sub>2</sub> , CH <sub>4</sub> and CO   | 12 months                |
| Level 2 | Trace gas concentration measurements from whole air samples  | 12 months                |
| Level 3 | Spatially extensive, continuous estimates of soil moisture, soil freeze/thaw state, inundation state and soil surface temperature along CARVE flight lines | 12 months                |
| Level 3 | Spatially extensive, continuous estimates of <i>in situ</i> and column CO <sub>2</sub> , CH <sub>4</sub> and CO along CARVE flight lines                   | 12 months                |
| N/A     | Surface measurement data   | Investigation Closeout   |

### 4.5.2 SCIENCE DATA REQUIREMENTS

- The CARVE science data product formats shall conform to one of the ESD-approved Data System Standards.
- The CARVE science data products shall have accompanying spatial, temporal and product metadata that conforms to ESD-approved metadata specifications.

### 4.5.3 APPLIED SCIENCE DATA

- The CARVE Investigation team shall participate in NASA-sponsored Venture Class Missions data product application workshops.

## 4.6 INVESTIGATION SUCCESS CRITERIA

The CARVE Investigation shall be successful if it

- Conducts aircraft measurement campaigns in the Alaskan Arctic during the growing season over multiple years
- Records airborne remote sensing measurements of surface freeze/thaw state, soil moisture, and inundation state with coincident measurements of

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atmospheric concentrations of the greenhouse gases carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>)

- c) Uses CARVE measurements to estimate Alaskan Arctic carbon fluxes
- d) Delivers calibrated science data and geophysical data products for use by the scientific community

## **5.0 NASA INVESTIGATION COST REQUIREMENTS**

### **5.1 COST**

- a) The CARVE investigation life cycle cost (LCC) shall not exceed \$27.9M. The LCC includes the cost for the formulation, implementation, operations, calibration, validation, and science data analysis costs to generate the products in Table 1. It also includes Investigation reserves held at JPL and managed by the PI and Project Manager.

### **5.2 COST MANAGEMENT AND SCOPE REDUCTION**

- a) Provided that Program Level Requirements are preserved, and that due consideration has been given to the use of budgeted contingency and planned schedule contingency, the CARVE Investigation shall pursue scope reduction and risk management as a means to control cost.
- b) The Investigation Project Plan shall include potential scope reductions and the time frame in which they could be implemented. If other methods of cost containment are not practical, the reductions identified in the Investigation Project Plan may be exercised.
- c) Scope reductions from Baseline Science requirements (Section 4.1.1) to Threshold Science requirements (Section 4.1.2) or potential scope reductions affecting these Program Requirements shall be agreed to by the officials represented on the approval page of this document.

### **5.3 SCHEDULE AND INVESTIGATION CLOSEOUT**

- a) CARVE science operations shall begin no later than Summer 2013.
- b) The CARVE Investigation Closeout shall occur within 60 months from Authorization to Proceed (ATP) on September 28, 2010.
- c) Final verification of the CARVE Program Level Requirements and Investigation Success Criteria shall be delivered at the Investigation Closeout.

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## **6.0 MULTI-INVESTIGATION NASA FACILITIES**

The CARVE Investigation does not use any multi-investigation NASA facilities.

## **7.0 EXTERNAL AGREEMENTS**

The CARVE Investigation shall require no flight hardware or flight software contributions from organizations outside of NASA to meet its Baseline or Threshold Science Requirements (Sec. 4.1.1 and 4.1.2), precluding the need for external agreements for flight hardware or software contributions.

## **8.0 PUBLIC OUTREACH AND EDUCATION**

The CARVE Investigation team shall participate in ESSP Sponsored EV-1 Education and Public Outreach activities.

## **9.0 SPECIAL INDEPENDENT EVALUATION**

No special independent evaluation is required for the CARVE Investigation.

## **10.0 WAIVERS**

No waivers are required for the CARVE Investigation.




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& INVESTIGATION SUCCESS CRITERIA

## 11.0 REQUIRED APPROVALS AND CONCURRENCES

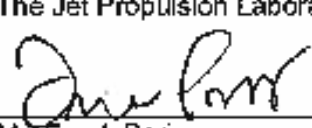
### APPROVALS:

  
Dr. Michael H. Freilich  
Director  
Earth Science Division  
Science Mission Directorate  
NASA Headquarters

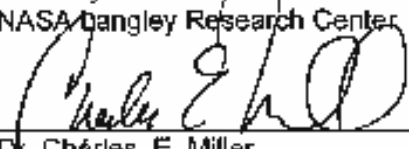
18 Jan 11  
Date

  
Dr. Diane L. Evans  
Director  
Earth Science and Technology Directorate  
The Jet Propulsion Laboratory

18 Jan 11  
Date

  
Mr. Frank Peri  
Program Manager  
Earth System Science Pathfinder Program  
NASA Langley Research Center


18 Jan 2011  
Date

  
Dr. Charles E. Miller  
Principal Investigator  
CARVE Investigation  
The Jet Propulsion Laboratory

18 Jan 2011  
Date

### CONCURRENCES:

NASA Headquarters

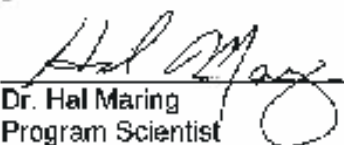
  
Dr. Stephen M. Volz  
Associate Director for Flight Programs  
Earth Science Division  
Science Mission Directorate  
NASA Headquarters

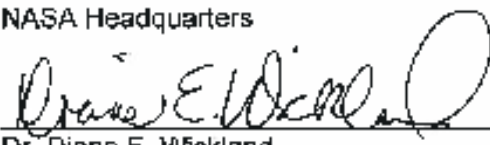
18 Jan 2011  
Date

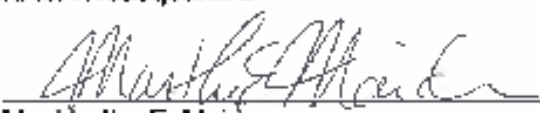
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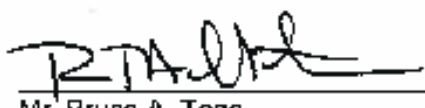
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CARVE Program-LEVEL REQUIREMENTS  
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 14 Jan 2011  
 Date  
 Dr. Hal Maring  
 Program Scientist  
 Earth Science Division  
 Science Mission Directorate  
 NASA Headquarters

 1/14/11  
 Date  
 Dr. Diane E. Wickland  
 Program Scientist  
 Earth Science Division  
 Science Mission Directorate  
 NASA Headquarters

 1/14/2011  
 Date  
 Ms. Martha E. Maiden  
 Program Executive  
 Earth Data Systems  
 Earth Science Division  
 Science Mission Directorate  
 NASA Headquarters

 1/18/2011  
 Date  
 Mr. Bruce A. Tagg  
 Director  
 Airborne Science Program  
 Earth Science Division  
 Science Mission Directorate  
 NASA Headquarters

 1/14/2011  
 Date  
 Dr. Melody A. Avery  
 Program Executive  
 Earth Venture-1  
 Science Mission Directorate  
 NASA Headquarters

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& INVESTIGATION SUCCESS CRITERIA

**NASA Langley Research Center**



Mr. Todd C. Denkins  
EV-1 Mission Manager  
Earth System Science Pathfinder Program  
NASA Langley Research Center

4/18/11  
Date

**The Jet Propulsion Laboratory**



Mr. Steven J. Dinardo  
Project Manager  
CARVE Investigation  
The Jet Propulsion Laboratory

1/18/11  
Date

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## **Appendix O Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ)**

### **O.1 DISCOVER-AQ DESCRIPTION**

The overarching objective of the DISCOVER-AQ investigation is to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. To diagnose air quality conditions from space, reliable satellite information on aerosols and ozone precursors needs to be compared to surface- and aircraft-based measurements at highly-correlated times and locations. DISCOVER-AQ will provide an integrated dataset of airborne and surface observations relevant to the diagnosis of surface air quality conditions from space.

DISCOVER-AQ will provide systematic and concurrent observations of column-integrated, surface, and vertically-resolved distributions of aerosols and trace gases relevant to air quality as they evolve throughout the day. This will be accomplished with a combination of two NASA airborne platforms (B-200 and P-3B) sampling in coordination with re-locatable and fixed surface networks. One aircraft will be used for extensive in-situ profiling of the atmosphere while the other will conduct both passive and active remote sensing of the atmospheric column extending below the aircraft to the surface. These aircraft will repeatedly overfly instrumented surface locations continuously monitoring both column and surface conditions for select variables throughout the day.

DISCOVER-AQ will focus on NASA's goals to study the Earth from space to increase fundamental understanding and to enable the application of satellite data for societal benefit. DISCOVER-AQ aligns with priorities for both the Atmospheric Composition Focus Area and the Applied Sciences Air Quality Program at NASA. Fundamentally, DISCOVER-AQ will provide data needed to critically examine the ability to determine surface air quality conditions from space.

The P-3B in-situ trace gas measurement techniques are: thermal disassociation, laser induced fluorescence, chemiluminescence, IR absorption spectrometer, LI-COR 6252, diode laser spectrometer, and hygrometer and proton transfer reaction-mass spectrometer. Measurements are NO<sub>2</sub>, peroxy nitrates, alkyl nitrates, HNO<sub>3</sub>, O<sub>3</sub>, NO<sub>x</sub>, CH<sub>2</sub>O, CO<sub>2</sub>, CO, CH<sub>4</sub>, H<sub>2</sub>O, methanol, acetaldehyde, acetone, isoprene, acetonitrile, benzene, toluene, C8 aromatics, and C9 aromatics.

The P-3B airborne in situ aerosol measurement techniques are: condensation particle counter, mobility particle sizers, Droplet Measurement Technologies (DMT) spectrometer, optical particle counter, aerodynamic particle sizer, condensation nuclei counter, nephelometer, soot absorption photometer, Radiance Research (RR) nephelometer, DMT particle soot photometer, particle into liquid sampler chromatograph and total organic carbon. Measurements are ultrafine NV CN; particle size; CN spectra; scattering at 450, 550, and 700nm; absorption at 467, 530, and 660 nm; humidity dependence of scattering; black carbon; soluble ion composition; and water soluble organic carbon.

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The P-3B meteorological measurements are: pressure, wind speed, ground speed, temperature, dew/frost point, and NO<sub>2</sub> photolysis frequency.

The ground station instruments are: Pandora, Cleo, and Native. The measurements are: O<sub>3</sub> total column, NO<sub>2</sub>, CH<sub>2</sub>O, SO<sub>2</sub>, H<sub>2</sub>O, BrO, O<sub>3</sub> profile, NO<sub>2</sub> profile and aerosol properties.

The B-200 remote sensing instruments are: High Spectral Resolution LIDAR (HSRL) and Airborne Compact Atmospheric Mapper (ACAM). The measurements are: aerosol backscatter at 532 and 1064 nm, aerosol extinction at 532 nm, aerosol optical depth at 532 nm, O<sub>3</sub>, NO<sub>2</sub>, and CH<sub>2</sub>O.

All instrumentation is in the TRL-9 category and has a flight heritage of a decade or longer.

The PI is from LaRC, and LaRC is responsible for project management.

Cost: \$30.0M (2010-2015)

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## **Appendix P Hurricane and Severe Storm Sentinel (HS3)**

### **P.1 HS3 DESCRIPTION**

Close to 100 million Americans now live within 50 miles of a coastline, thus exposing them to the potential destruction caused by a land-falling hurricane. While hurricane track prediction has improved in recent decades, improvements in hurricane intensity prediction have lagged, primarily as a result of a poor understanding of the processes involved in storm intensity change. The Hurricane and Severe Storm Sentinel (HS3) is a five-year project targeted to enhance our understanding of the processes that underlie hurricane intensity change in the Atlantic Ocean basin. HS3 will determine the extent to which either the environment or the processes internal to the storm are significant to intensity change.

The investigation objectives will be achieved using two Global Hawk (GH) Uninhabited Aerial Systems (UAS) with separate comprehensive environmental and over-storm payloads. The high Global Hawk flight altitudes allow over-flights of most vertical storm convection and sampling of upper-tropospheric winds. Deployments from NASA's Wallops Flight Facility and 30-hour flight durations will provide access to unrestricted air space, coverage of the entire Atlantic Ocean basin, and on-station times up to 10-24 hours depending on storm location. Deployments will be from mid-August to mid-September 2012-2014, with ten 30-hour flights per deployment, providing an unprecedented and comprehensive data set for approximately nine to twelve hurricanes.

HS3 is focused on the fundamental NASA Earth Science goal to "Study Earth from space to advance scientific understanding and meet societal needs" and NASA's Research Objective to "enable improved predictive capability for weather and extreme weather events." HS3 complements NASA's Weather Focus Area and Hurricane Science Research Program.

A Scanning High-resolution Interferometer Sounder (S-HIS) will provide temperature and relative humidity and has flown on four different platforms since 1998. A Tropospheric Wind LIDAR Technology Experiment (TWiLiTE) Doppler LIDAR will provide continuous wind profile and is building a new telescope under the ESTO Program to fit within the GH compartment. An Airborne Vertical Atmosphere Profiling System (AVAPS) dropsonde will provide wind, temperature and humidity profiles and has been used for several decades. A CPL will provide aerosol and cloud layer vertical structure and was first deployed in 2000. A High-Altitude Imaging Wind and Rain Airborne Radar (HIWRAP) scanning Doppler radar will provide 3-D wind and precipitation fields and was designed for GH in 2007. A Hurricane Imaging Radiometer (HIRAD) hurricane imaging multi-frequency interferometric radiometer will provide surface winds and rainfall and is based on the stepped frequency microwave radiometer (SFMR) and flies on the WB-57 at the end of 2009. A High Altitude MMIC sounding radiometer (HAMSR) will provide temperature, water vapor, liquid water profiles, total precipitated water, sea surface temperature, and vertical precipitation profiles first flew in 2001.

The PI and the relevant Center Management Council are at GSFC; the Project Manager and project management responsibilities are at ARC.

Cost: \$29.7M over five years (2010-2015)

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## Appendix Q Future EV Projects

### Q.1 PROJECTS DESCRIPTION

The 2007 Decadal Survey first characterized the Venture class missions, describing them as follows:

*“Priority would be given to cost-effective, innovative missions rather than those with excessive scientific and technological requirements. The Venture class could include stand-alone missions that use simple, small instruments, spacecraft, and launch vehicles; more complex instruments of opportunity flown on partner spacecraft and launch vehicles; or complex sets of instruments flown on suitable sub-orbital platforms to address focused sets of scientific questions. These missions could focus on establishing new research avenues or on demonstrating key application-oriented measurements. Key to the success of such a program will be maintaining a steady stream of opportunities for community participation in the development of innovative ideas, which requires that strict schedule and cost guidelines be enforced for the program participants.”*

In response to this recommendation, NASA established the EV portfolio of investigations and assigned the investigations to the ESSP Program. The EV-1 NRA was released during 2009 and five proposals were selected during 2010 (see Appendices L through P.)

Future EV investigations will be competed annually (depending on funding) and are broadly categorized as either Orbital, Sub-orbital or Instrument investigations.

- **Orbital:** EV Orbital investigations are stand-alone investigations that use simple, small instruments, spacecraft, and launch vehicles. EV five-year orbital investigations will be competed every four years, and will be cost-capped at approximately \$150M. The Announcement of Opportunity (AO) procurement process is expected to occur in two steps, where the first step narrows the field to three offerors and the second step competitively down-selects to a single selection.
- **Sub-orbital:** EV Sub-orbital five-year investigations are composed of complex sets of instruments flown on suitable sub-orbital platforms to address focused sets of scientific questions. EV sub-orbital investigations will be competed every four years, and will be cost-capped at approximately \$150M total for up to five selections. Each individual selection will be cost-capped at approximately \$30M, and the NRA procurement process is expected to occur in one step.
- **Instrument:** EV Instrument investigations are composed of more complex instruments of opportunity flown on partner spacecraft and launch vehicles. EV instrument investigations will be competed every year, and will be cost-capped at approximately \$90M total. The Stand-Alone Mission of Opportunity Notice (SALMON) procurement process will occur in one step, resulting in one or more selections. Each selection will be for a duration of five years, which does not include flight operations or science data activities.

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Table Q-1 details the schedule for EV solicitations during the next several years.

**Table Q-1: Future EV Projects Development**

| EV Name      | Type            | Solicitation | Selection | Launch/Delivery |
|--------------|-----------------|--------------|-----------|-----------------|
| <b>EV-2</b>  | Full Orbital    | 2011         | 2012      | LRD ~2017       |
| <b>EV-I1</b> | Instrument Only | 2011         | 2012      | Del ~2016       |
| <b>EV-I2</b> | Instrument Only | 2012         | 2013      | Del ~2017       |
| <b>EV-3</b>  | Sub-orbital     | 2013         | 2014      |                 |
| <b>EV-I3</b> | Instrument Only | 2013         | 2014      | Del ~2018       |
| <b>EV-I4</b> | Instrument Only | 2014         | 2015      | Del ~2019       |
| <b>EV-4</b>  | Full Orbital    | 2015         | 2016      | LRD ~2021       |
| <b>EV-I5</b> | Instrument Only | 2015         | 2016      | Del ~2020       |
| <b>EV-I6</b> | Instrument Only | 2016         | 2017      | Del ~2021       |
| <b>EV-5</b>  | Sub-orbital     | 2017         | 2018      |                 |



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## Appendix R Functional Assignments for ESSP Personnel

**Table R-1: ESSP Management Responsibilities**

| Assignment   | ESSP Program Office | ESD | Notes  |
|--|---------------------|-----|--|
| Communicate Project performance issues and risks to Mission Directorate management and present recovery plans. |                     | X   | Program Office communicates issues and risks to ESD management. ESD has the lead to communicate Project issues to SMD AA. The Program Office supports ESD as needed in reporting to the SMD AA.  |
| Conduct planning, etc. to support the SMD AA in initiating the project selections process.                     |                     | X   | ESD has the lead to work Phase A. ESD works directly with the SMD AA in implementing the project selection process. The Program Office supports the selection process as directed by ESD, such as performing studies to assess the announcement release dates, putting contract in place, shadowing the selection process for understanding risk, etc. |
| Manage program resources.  |                     | X   | ESD controls the program futures line. Program Office controls Program Office budget to conduct oversight activities.  |
| Maintain programmatic oversight of the Projects and report their status periodically.                          | X                   | X   | Program Office provides programmatic oversight of Projects. Program Office provides weekly notes and monthly report to ESD. ESD provides programmatic oversight of the Program and the PEs report status of projects at the Flight Projects Review.  |
| Provide KDP recommendation on Projects to AA per NPR 7120.5  | X                   | X   | Program Office provides a Program Office recommendation to the AA at KDPs B to F. ESD provides Division recommendation at KDPs A to F.   |
| Manage/direct Program contracts/task orders.   | X                   | X   | Program Office function. Program Office manages and directs Program contracts and task orders with Projects. ESD Program Executive signs JPL task plans.   |
| Provide programmatic direction to ESSP Projects.   | X                   |     | Program Office has authority to issue direction to the Projects as needed. Program Office should make ESD aware of direction as appropriate.   |

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| Assignment   | ESSP Program Office | ESD | Notes  |
|--|---------------------|-----|--|
| Serve as NASA Point of contact ESSP Projects.  | X                   |     | Actions and direction to the Projects come from the Program Office. PE/PS/PA and ESSP MMs should work as a team to coordinate communication with Projects. The PE/PS/PA may contact the Project directly, but will keep the appropriate MM informed.               |
| Assess/monitor Project performance and take action, as appropriate, to mitigate risks. | X                   |     | Program Office has authority to take action or provide Project direction to mitigate risks. Program Office should make ESD aware of direction, as appropriate.   |
| Conduct monthly review with Projects   | X                   |     | Where there are existing meetings and forums that the Program Office can leverage, the Program Office will take advantage of these. If the Program Office is not receiving all needed information, a mechanism for receiving such information will be established. |
| Establish Project technical, schedule and cost status reporting.                       | X                   |     | Program Office has the lead to establish appropriate level and content of Project reporting to the Program and will coordinate with the PE/PS/PA to ensure their requirements are captured.  |

**Table R-2: ESSP Technical Responsibilities**

| Assignment  | ESSP Program Office | ESD | Notes  |
|---|---------------------|-----|--|
| Communicate Project technical issues and risks with recovery plans to the SMD AA.   |                     | X   | Program Office communicates through ESD. ESD has lead role to communicate with the SMD AA.   |
| Perform technical evaluation of proposed mission concepts.                          |                     | X   | ESD performs this using Phase A TMCO process. Pre-solicitation release, Program Office is supporting this activity. Post-solicitation release Program Office is observing. |
| Direct institution to perform technical evaluation of a Project within the Program. | X                   |     | Program Office function  |

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| Assignment  | ESSP Program Office | ESD | Notes  |
|---|---------------------|-----|--|
| Perform Program acceptance of resolution of high risk Project technical issues. | X                   |     | Program Office has authority to conduct reviews and accept Project technical assessments within the baseline. Program Office briefs ESD management on Program Office review and acceptance. Program Office to coordinate when "high risk" requires ESD management prior to acceptance. |
| Direct Project to perform special studies of high risk issues.                  | X                   |     | Program Office function  |
| Independently assess Project for technical risk.                                | X                   | X   | Program Office function  |
| Maintain technical oversight of the Projects.                                   | X                   | X   | Program Office function  |

**Table R-3: ESSP Schedule Responsibilities**

| Assignment   | ESSP Program Office | ESD | Notes   |
|--|---------------------|-----|---|
| Assess Program schedule performance.   |                     | X   | Program Office provides inputs (such as launch frequency assessments) to ESD. ESD conducts final evaluation of Program schedule performance.  |
| Control Level 1 Project Milestones.  |                     | X   | This is performed through the Program-Level Requirements Appendix to the Program Plan. Program Office provides inputs. SMD performs final approval.   |
| Establish/recommend Program Schedule Milestones (Announcement release, Project timing, etc.) | X                   | X   | Program Office performs studies of funding availability against Program cost threats and projected new Project cost profiles, and provides recommendations to ESD as to program-level schedule. ESD establishes final program-level milestones (i.e. announcement release dates). |
| Assess monthly Project schedule performance.   | X                   | X   | Program Office function   |
| Assess Project schedule for overall implementation strategy and credibility.                 | X                   | X   | Program Office function   |

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| Assignment   | ESSP Program Office | ESD | Notes   |
|--|---------------------|-----|---|
| Establish/control significant Project schedule milestones. | X                   |     | Program Office coordinates with Project and approves milestone dates which are not Level 1-controlled PLRA. |

**Table R-4: ESSP Cost Responsibilities**

| Assignment  | ESSP Program Office | ESD | Notes   |
|---|---------------------|-----|---|
| Program budget strategic planning.  |                     | X   | ESD function. Program Office supports.  |
| Final decisions and recommendations to SMD AA.  |                     | X   | ESD function  |
| Assess program-level cost performance.  |                     | X   | ESD leads this function. Program Office supports with data and analysis.  |
| Manage Program reserves.  | X                   |     | Program Office controls Program reserves. ESD approves Program reserves line.                                   |
| Assess total Program liens and threats.   | X                   |     | Program Office identifies and assesses Project and Program liens and threats related to Project implementation. |
| Establish funding priorities between Projects.  |                     | X   | ESD makes final decisions. Program Office has involvement and input into establishing priorities.               |
| Perform Risks and Trades analysis of Program budget impacts.                          | X                   | X   | Program Office performs analysis using ESD supplied guidelines and cost data.                                   |
| Perform cost studies to recommend announcement release timing or project start dates. | X                   |     | Program Office function   |
| Perform independent cost evaluation of poor performing projects.                      | X                   |     | Program Office function   |
| Independently assess project for liens and threats, track those with program impacts. | X                   | X   | Program Office function. Program Office provides assessments to ESD.  |
| Review and approve annual project budget submission to ESD.                           | X                   |     | Program Office function   |
| Gather project data and PPBE inputs.  | X                   |     | Program Office function   |
| Assess monthly cost performance.  | X                   | X   | Program Office function   |

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**Table R-5: ESSP Risk Responsibilities**

| Assignment  | ESSP Program Office | ESD | Notes   |
|---|---------------------|-----|---|
| Accept Program risks.   |                     | X   | ESD function. Program Office provides assessment and recommendations.   |
| Perform program-level risk assessment and conduct activities to mitigate. | X                   |     | Program Office function.  |
| Utilize Program resources to assist in mitigation of Project risks        | X                   |     | Program Office function. Program Office uses combination of existing office core support staff and modulated technical support to assist Project in mitigating risks and reserves.  |
| Accept Project risks.   | X                   |     | Program Office has authority to review and accept risks within the baseline. Program Office briefs ESD management as appropriate. Program Office uses discretion on when "high risk" requires coordination with ESD management prior to acceptance. |
| Independently assess Projects for risks.                                  | X                   | X   | Program Office function   |
| Assess adequacy of Project risk mitigation plans.                         | X                   | X   | Program Office function   |

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## **Appendix S Project Information Needed for Monthly Assessments and Reporting**

(As of the end of the monthly period; where appropriate for schedule or trend, show current at middle of 12-month period; variance explanation required for  $\geq \pm 10\%$  variation)

- **Schedule**
  - 3 shortest critical paths
  - Schedule slack vs. plan trend and variance explanation
  - Progress vs. plan for meeting critical milestones and variance explanation
  - Scheduled events completed vs. planned and variance explanation
  - New vendor/contractor deliveries vs. plan and variance explanation
- **Technical**
  - Performance measurement trends
  - Deviations and waivers submitted, approved
  - Newly opened and closed action items
  - New documents available vs. plan
  - Documents or drawings released vs. plan
  - CBE vs. allocation for major project elements and margin vs. plan for mass, power, data, CPU, etc.
- **Financial**
  - Earned Value
  - Estimate to complete
  - Cost variance; commitments, obligations and costs vs. plan and variance explanation
  - Total at completion and variance explanation
  - Outstanding new liens and encumbrances
  - Reserve funds available vs. used
  - Funding available vs. plan
  - Provide WBS breakdown of cost accruals, obligations, and commitments period when variance for total project first exceeds  $\pm 10\%$  and for succeeding periods until all WBS breakdowns indicate variance of less than  $\pm 5\%$
  - For first period when a new plan (baseline) is used, provide monthly projection of total Project cost accrual, obligations, and commitments to Project completion along with explanation for any anticipated variance from current contract value of 5% at completion.
- **Risk**
  - $5 \times 5$  matrix
  - New or revised individual risk descriptions
  - New mitigation effort plans
  - New top 10 risks items
- **Staffing**
  - Complement onboard vs. plan and explanation of variance
- **SMA**
  - New and closed problem/failure reports
  - Identifying government mandatory inspection points for next period

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- Number of material inspections planned vs. completed for period
- Number of MRB actions completed per period and number pending for next period
- Number of deviations and waivers initiated for period vs. number approved vs. number recycled for revisions
- Number of planned vs. completed audits/assessments and open vs. closed findings
- Science
  - Days of new raw data available vs. plan
  - Days of new Level 1 product available vs. plan
  - Days of raw and processed data into archive vs. plan
  - Completed coding lines of code vs. plan
  - Completed testing/validation lines of code vs. plan
- Other
  - CCNs submitted and completed
  - Contractor new concerns/issues
  - Contract new modifications
  - New contracts vs. plan and variance explanation
  - Support readiness/issues of other organizations
  - New threats to Level 1 requirements
  - Pending near term key events
  - New Lessons Learned documents
  - New dissents in work
  - New documents baselined vs. plan and variance explanation
- Project Manager's Assessment
  - G,Y,R assessment for Technical, Cost, Schedule, Risk, Programmatic, Overall
  - Significant accomplishments
  - Significant new status
  - New Problems

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## **Appendix T ESSP Management Approach for EV-1 Projects**

The EV-1 Projects are managed by the ESSP Program Office. The primary goal of the ESSP Program Office is to facilitate Project success. This is accomplished by continually assessing risks to ensure project-level processes and practices are commensurate with NASA investment and risk tolerance. The ESSP Program Office also provides technical expertise to assess ESSP Project risk and performance, identifies and realizes synergistic opportunities across Projects, advocates for Projects, and works closely with HQ on behalf of the Projects.

The term “Projects” is used to describe these activities. However, the management approach of EV-1 applies NPR 7120.8, as well as best practices from the sub-orbital community, the implementing Centers and NPR 7120.5. The ESSP Program Office will provide guidance on review plans, practices and procedures, and the Projects shall propose plans that will be assessed by the ESSP Program Office to ensure they are commensurate with the NASA investment and risk tolerance.

An ITA is the required mechanism for agreement between Center PIs and the ESSP Program Office to release funds to the NASA implementing Centers. Agreements with JPL PIs will be in the form of Task Plans. Agreements with University PIs will be in the form of contracts. For agreements within the Project Team, the ESSP Program Office will have funds transferred to FFRDCs, other Centers and other agencies, but the PI is responsible for developing and finalizing all agreements between the PI and the implementers.

Each EV-1 Project is cost capped and schedule constrained, so management of cost, schedule, reserves and de-scopes is critical. The overall schedule and budget reserves and de-scope options are identified in its selection proposals. The PI has two choices for managing reserves: (1) to manage all project-level reserves as proposed in his/her selection proposal or (2) to keep the reserves at ESD and potentially “pool” those reserves with other PIs. For EV-1 Projects where the PI is not at the same institution as the implementing organization, the reserves are to be held at ESD until direction from the PI to disperse those funds is received. The PI may choose when during the project life cycle to disperse those funds to the implementing organization. When de-scopes are indicated, the ESSP Program Office assesses them against the mission success criteria and minimum mission success criteria. At the Investigation Concept Review (ICR), the ESSP Program Office assesses the cost and schedule along with the cost/schedule reserves and descope options. The Programmatic Baseline will be approved at KDP C. The ESSP Program Office continually monitors progress through weekly, monthly, and quarterly reports/meetings/telecons. If at any time the projected cost exceeds the cost cap, or minimum Level 1 requirements are not being met, the Program Manager may recommend a Termination Review to the SMD AA.

The PI shall support weekly telecons with the ESSP Program Office to focus on tasks, progress, and issues. The PI shall provide monthly reports to the ESSP Program Office and conduct monthly status review meetings that the ESSP Program Office will attend. These monthly meetings may be held in conjunction with Center management meetings, if deemed appropriate. In addition to the monthly meeting, there are quarterly face-to-face meetings held among the PI,



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PS, and the ESSP Program Office to discuss science and programmatic strategic planning that will assure successful completion of Level 1 requirements. The PI or the ESSP Program Office may convene ad hoc meetings when needed.

Monthly reports shall include but are not limited to:

- Technical Performance
  - Major Accomplishments
  - Science Status
  - Top ten problems status
  - Risks and risk mitigation status
- Schedule performance
  - Schedule progress at WBS level 3
  - Schedule slack status
  - Schedule reserve status
  - Schedule variance and explanation
- Financial
  - Funding Status
  - Cost Performance at WBS level 3
  - Funding actual vs. planned (committed, obligated and costed)
  - Variance explanations
  - Funding reserve status – Liens & encumbrances
- Programmatic
  - Contractor concerns/issues
  - Staffing, and variance explanations
  - Facility/Asset status report – discuss status of facilities, airborne assets, instruments and other necessary assets or equipment
  - Other

The ESSP Program Office will provide guidance on the EV-1 Projects review process (derived from NPR 7120.8 and EV-1 NRA). The PI shall develop a plan based on this guidance, and the plan will be reviewed for approval by the ESSP Program Office.

There will be an IRT that assesses the EV-1 Projects at life cycle reviews. The Chair for this IRT will be nominated by the ESSP Program Office and approved by the SMD AA. The IRT Chair and the ESSP Program Office will document the planned interaction with the Projects in a ToR. The remaining review team members will be nominated by the ESSP Program Office and the Chair and then approved by the SMD AA. This Review Team may participate in the Projects' internal reviews and will be in place for the Investigation Concept Review.

The Level 1 Requirements will be developed among the PI, PS, PE, and the ESSP Program Office. The Level 1 Requirements will identify the minimum mission success criteria and full mission success criteria in order to assess de-scope options.

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The EV-1 Projects shall use a documented process to identify risks, assess likelihood and consequence, and develop mitigation plans. Significant risks will have mitigation plans which will be reviewed monthly by the ESSP Program Office.

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National Aeronautics and Space Administration  
**Headquarters**  
Washington, DC 20546-0001



Reply to Attention: ESD/Earth System Science Pathfinder Program Office

TO: Program Manager

FROM: Associate Director for Flight Programs

SUBJECT: Management of the Earth Venture-1 Element of the Earth System Science Pathfinder (ESSP) Program

This document outlines high-level management requirements that are common to the five investigations that comprise the Earth Venture-1 (EV-1) element of the ESSP program. In addition to these common management processes, each Principal Investigation-led EV-1 investigation also has an individual program-level requirements document, and Investigation Project Plan that documents management requirements and processes that are investigation-specific.

#### Background:

There are five independent scientific investigations comprising the first element of the new Earth Venture series of ESSP program elements. Earth Venture program elements were designed to address recommendations by the National Research Council in the 2007 Decadal Survey. As the first element of a planned series, EV-1 investigations involve extensive airborne sampling of earth systems to answer focused multi-disciplinary science questions that are relevant to NASA's strategic plan.

EV-1 was formulated as a research announcement in an appendix to Research Opportunities in Space and Earth Sciences (ROSES), which includes a description of expectations for investigation management. Management of these investigations blends aspects of two traditional types of NASA projects; aircraft field experiments that have been managed by research discipline program scientists, and small ESSP satellite missions that have been managed through a program office. As a new blended element, EV-1 management processes have been adjusted to provide flexibility needed for investigation success. The purpose of this memo is to update and augment the high-level investigation management processes originally described in the ROSES research announcement.

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#### Governing Processes:

The five EV-1 investigations are managed under NPR 7120.8 as a Portfolio Research element. The independent reviews and key decision points for EV-1 investigations are described later in this document. Aircraft safety and operations for each investigation are implemented at the NASA Center designated to manage a particular NASA or portfolio airplane. NASA aircraft safety and operations processes are governed by NPR 7900.3B and by NPD 7900.4C, including required airworthiness and flight-readiness reviews.

#### Decision Authority:

EV-1 investigations were selected from a ROSES solicitation, which delegates Decision Authority to the Research and Analysis Program of the Earth Science Division (ESD). However, the ESSP program in the Flight Programs of the ESD will manage these investigations. The EV-1 investigations also contain a significant Applied Science component. The Science Mission Directorate Associate Administrator delegates Decision Authority to the ESD Director for these multifaceted investigations.

#### Independent Reviews and Key Decision Points:

A series of independent reviews will be held for each EV-1 investigation. The purpose of these reviews is to reduce risk to the investigation by providing expert assessment of investigation development and implementation during progressive stages of the investigation lifecycle. Investigation reviews will include an investigation concept review, investigation design review, investigation readiness review, and post-deployment assessment review. The ESSP program office will establish a review team with the appropriate expertise, in conjunction with the implementing NASA Center. The review team will advise the investigation, implementing NASA Center, the Earth System Science Pathfinder Program Office (ESSPPO), and the convening authorities about investigation technical and programmatic approach, risk posture, and progress against the program/project baseline. A baseline term of reference for these independent reviews will be approved by the ESSP Program Manager, with concurrences by the Director of the ESD, Director of Flight Programs, and implementing NASA Center.

Each EV-1 investigation will have an Investigation Confirmation Review, Key Decision Point (KDP) C in 7120.8, to be held by NASA Headquarters as soon as possible after a successful IDR. The KDP-C will allow the NASA Decision Authority to determine investigation readiness to continue forward with investigation implementation, with the approval and recognition of NASA Agency commitment. The KDP-C will include a briefing to the Decision Authority by the independent review team, the ESSPPO, the implementing NASA Center, and the investigation PI. The KDP-C will conclude with a Decision Memo signed by the Decision Authority. The Decision Authority will determine if optional KDP's D and E are required during implementation. A KDP-F will be held by NASA Headquarters to initiate each investigation's movement from implementation into closure, and the PI will provide

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Lessons Learned as described in 7120.8. Each investigation will complete closeout 60 months after obtaining authority to proceed.



Dr. Stephen M. Volz

cc:

Science Mission Directorate/S. Black  
Earth Science Division/P. Luce

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- B. Tagg
- L. Tsaoussi
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## **Appendix U Education and Public Outreach Policy**

### **Science Mission Directorate Policy**

#### **Policy and Requirements for the Education and Public Outreach Programs of SMD Missions**

##### **SMD Policy Document SPD-18**

Recommended by SMD Science Management Council, January 28, 2010

Approved by SMD Associate Administrator, Edward J. Weiler, January 28, 2010

Responsible SMD Official: SMD Lead for Education and Public Outreach

### **1. Overview**

#### **1.1 Principles**

SMD requires that all missions have robust and substantial education and public outreach (E/PO) programs. These E/PO programs must be consistent with SMD's principles for mission E/PO:

- SMD missions must have an E/PO program that supports NASA's strategic goals and objectives for education and outreach, contributes to NASA's education portfolio, and is aligned with SMD's E/PO portfolio.
- SMD missions must have an E/PO program whose quality has been demonstrated through independent, external review and assessment.
- SMD missions must have an E/PO program that is funded with at least 1% of the total prime mission cost excluding launch vehicle.
- SMD missions will designate an E/PO Lead who has the qualifications and experience necessary to successfully implement the mission's E/PO program.
- SMD missions will partner with NASA and non-NASA organizations as appropriate in order to increase the quality and reach of the E/PO program.

#### **1.2 Rationale for Mission E/PO Requirements**

The SMD E/PO lead is required to report on the SMD E/PO portfolio and show that it aligns with the NASA Education portfolio. The Lead is responsible for reporting E/PO metrics for SMD and reporting how SMD E/PO funding is contributing to the NASA Education portfolio's outcomes and objectives. This reporting is a component of NASA's PART measures that are required by OMB. This responsibility cannot be delegated to the Programs or the Centers.

#### **1.3 Management Handbook**

The governing project requirements (NPR 7120.5, SMD Management Handbook) are incomplete in specifying how such E/PO programs will be approved, managed, and reviewed. This document supplements NPR 7120.5 and the SMD Management Handbook in order to provide the necessary policies and requirements.

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The requirements in this document are added to the KDP checklists in the SMD Management Handbook.

## 2. Requirements

### 2.1 Management requirements

(a) SMD missions must designate an E/PO Lead (or point of contact) responsible for developing and implementing the Mission E/PO program. The mission E/PO Lead must report E/PO activities, progress, and accomplishments to the SMD Division E/PO Lead. This reporting may be through a designated member of the mission project management team, e.g. the PI or project scientist.

(b) SMD missions must have an E/PO plan that addresses NASA and SMD E/PO goals and objectives, draws from the mission's science and technical content, and is aligned with NASA and SMD E/PO portfolio. The mission E/PO plan must be approved by the SMD Science Division Director and SMD Lead for E/PO.

(c) SMD Science Divisions may provide additional requirements or guidelines according to their needs.

(d) In the case of a tightly focused program of strategic missions, the SMD Science Division Director may recommend that E/PO leadership and planning for all missions in the program be delegated to the Program Office. Such delegation requires concurrence by the SMD Lead for E/PO and approval by the SMD AA. The Program Office is required to meet all E/PO management/planning and reporting requirements for all missions in the program. In addition the Program Office is required to submit an E/PO PPBE annually.

(e) Additional policy guidelines for AO-selected missions. AOs provide the initial guidance for the E/PO policies governing PI-led missions or PI-led instrument investigations. Default policies are

- PI-led missions will allocate at least 1% of the PI-managed mission cost cap to the core E/PO program. No E/PO plan is due with the Step 1 proposal. An initial E/PO plan including identification of an E/PO lead is due with the Step 2 Concept Study Report (CSR). Student collaborations, while encouraged, are not considered part of the core E/PO program.
- PI-led instrument investigations will not generally have independent core E/PO programs. Selected instrument teams will participate in the mission E/PO program. Activities will be negotiated after selection and the funding for E/PO activities will come from the mission E/PO budget, not the instrument team budget.
- With approval by the SMD AA, AOs may have different policies from these default policies.

SMD may levy E/PO requirements on AO-selected PI-led missions and instruments beyond those in the AO. For instance, for missions selected from AOs with an E/PO requirement of less than 1%, SMD can provide additional funding to accompany a requirement that E/PO spending be raised from the AO's minimum to 1%.

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## 2.2 Funding requirements

- (a) SMD missions must have an E/PO program that is funded with at least 1% of the total prime mission cost excluding launch vehicle. Exceptions require approval by the SMD AA.
- (b) The E/PO budget is fenced off from the rest of the project budget. Reductions to the approved E/PO budget require the concurrence of the SMD E/PO Lead and the SMD Science Division Director.
- (c) SMD mission E/PO budgets must be distributed throughout the mission development and operation phases. No E/PO funding will be available before KDP-C except for the nominal funding required to develop the E/PO plan. No more than 35% of E/PO funding (through prime mission) may be allocated before launch; at least 65% of the budget must be allocated for Phase E. Exceptions require approval by the SMD Science Division Director and SMD Lead for E/PO.
- (d) For SMD missions that were Confirmed prior to the effective date of this Policy and do not meet the minimum funding requirement, the Division can provide additional funding to accompany a requirement that E/PO spending be raised from the AO's minimum to 1%.

## 3. Reporting, Review, and Approval

### 3.1 Development and Approval of the Mission E/PO Plan

- (a) The preliminary E/PO plan must be developed during Phase A. Review and comment (not approval) of the initial E/PO plan is a KDP-B gateway product. Review and comment is provided by the Division E/PO lead. For missions downselected through a competitive Phase A, review and comment is also provided by the E/PO evaluation panel.
- (b) The final E/PO plan must be developed during Phase B and must address/resolve the comments and feedback provided at KDP-B. Approval of the final E/PO plan is a KDP-C gateway product. Review and concurrence is provided by the Program Scientist/Program Executive and the Division E/PO lead. Approval is provided by the SMD Science Division Director and SMD Lead for E/PO.
- (c) On the basis of the final E/PO plan an implementation plan must be developed. The implementation plan shall include detailed budgets, milestones, and timelines. Approval of the final E/PO plan is a CDR gateway product. Review and concurrence is provided by the Program Scientist/Program Executive and the Division E/PO lead. Approval is provided by the SMD Science Division Director and SMD Lead for E/PO.

### 3.2 Reporting for the Mission E/PO Program

- (a) Requirements for regular (weekly, monthly, quarterly, etc.) reporting of the mission's E/PO activities will be per the E/PO plan. Such reporting will be from the mission or program (e.g.



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E/PO lead through the PI/PM) to the Division E/PO lead with copy to the Division E/PO forum and the Program Executive/Program Scientist.

(b) Missions are also expected to provide reporting as appropriate in other venues: project reports, science team meetings, Division E/PO forum meetings, etc. Mission E/PO leads are also expected to participate in monthly Division E/PO forum telecons. The Division E/PO lead is responsible for tracking reporting (from program office, forums, science team meetings).

(c) The Division E/PO lead will ensure that the SMD Lead for E/PO receives a summary of Division E/PO reports.

(d) SMD is responsible for NASA Office of Education reporting and portfolio management. Reporting will be aided by the Division E/PO forums and the Division E/PO leads. Division E/PO forums, in consultation with Division E/PO leads, will assist mission E/PO leads in reporting through OEPM (Office of Education Program Management) for Office of Education reporting and portfolio management.

### 3.3 Assessment and Review

(a) Mission E/PO programs are expected to include evaluation plans. These evaluation plans will be described in the final E/PO plan and funded within the mission E/PO budget.

(b) Mission E/PO programs will be reviewed as part of a Division's Senior Review for operating missions. When divisions do not have bi-annual Senior Reviews, operating mission E/PO programs will be reviewed biannually through a standalone E/PO-only senior review-like process.

### 3.4 Canonical Timeline for Development and Approval of a Mission E/PO Plan

|  | PI-led (AO competed)<br>Mission | Strategic (directed)<br>Mission |
|--|---------------------------------|---------------------------------|
| E/PO statement of commitment           | Step 1 proposal                 | N/A                             |
| Preliminary E/PO plan                  | Step 2 CSR                      | Phase A                         |
| Review and comment of preliminary plan | Downselect                      | KDP-B                           |
| Final E/PO plan                        | Phase B                         | Phase B                         |
| Approval of final plan                 | KDP-C                           | KDP-C                           |
| Implementation plan                    | Phase C                         | Phase C                         |
| Approval of implementation plan        | CDR                             | CDR                             |

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### 3.5 Approval Authority for a Mission E/PO Plan

|   | Review and Concurrence  | Approval                            |
|---|---|-------------------------------------|
| Preliminary E/PO plan                       | Division E/PO Lead<br>(review only)                             | N/A                                 |
| Final E/PO plan                             | Program Scientist /<br>Program Executive;<br>Division E/PO Lead | Division Director;<br>SMD E/PO Lead |
| Implementation plan                         | Program Scientist /<br>Program Executive;<br>Division E/PO Lead | Division Director;<br>SMD E/PO Lead |
| Delegation to Program Office                | Division Director;<br>SMD E/PO Lead                             | SMD AA                              |
| Exception to 1% budget requirement          |   | SMD AA                              |
| Reductions to E/PO budget                   | Division Director;<br>SMD E/PO Lead                             | (budget process)                    |
| Exceptions to budget phasing<br>requirement |   | Division Director;<br>SMD E/PO Lead |